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Nuts & Volts

March 2004

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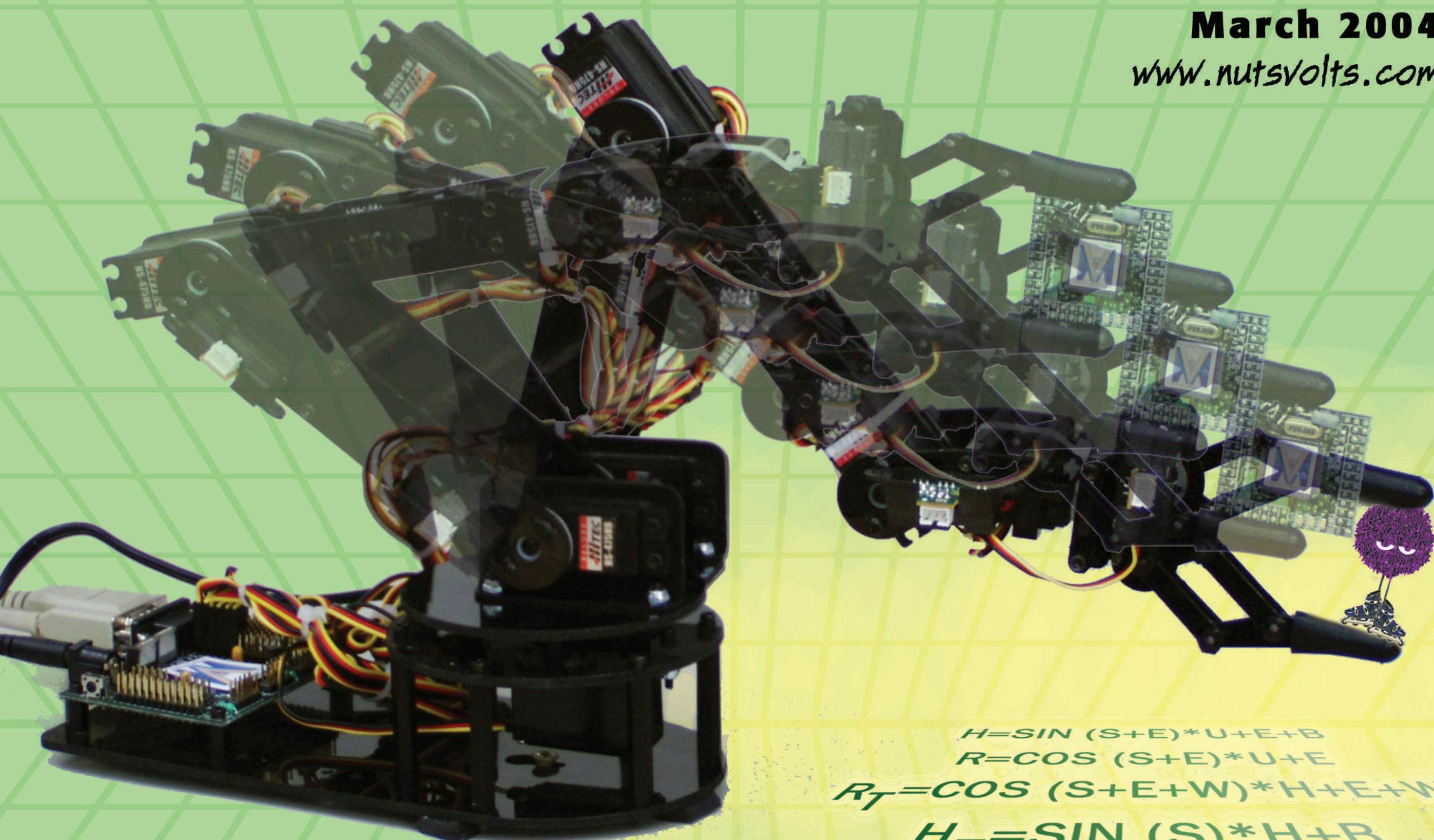

H=SIN (S+E)*U+E+B

R=COS (S+E)*U+E

R_T=COS (S+E+W)*H+E+W

H_E=SIN (S)*H+B

R_E=COS (S)*H

Inverse Kinematics: A UNIVERSAL ROBOTICS CONTROLLER

- BeforeTheWeb.com
- Yoga For Your HDD
- Shoot Those Troubles
- Interfacing With Transistors

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Dear Nuts and Volts:

I modified a Panasonic remote for use in controlling a project I am making. The photo included here shows the label, which actually looks better than what the digital photo shows. It seems that the digital photo emphasizes imperfections, whereas the eye doesn't see them as clearly on the real thing.

The label is made in a similar way to what Gerald Fonte suggested in his recent article (*Nuts & Volts*, February 2004, "Making Your Own Custom Membrane Switches") — using graphics printed with an ink jet printer onto a sticky paper label stock, then applying transparent tape on top for durability. I used a jeweler's magnifying headpiece and a boxcutter to cut the holes for the buttons.

I came up with the label idea independently. It's a lot of fun making a label that looks as good as what this method can produce. The control communicates with the Tiny IR circuit, a kit sold by Bob Grieb on the Internet for around $23.00. **www.pics.com/~grieb/IR.htm**

Grieb's circuit can "learn" the IR signal from just about any remote and translate it into one of eight latched TTL level outputs. I found the smallest remote I could — which is the Panasonic in the photo. I took it apart, cut down the excess rubber buttons so they wouldn't stick up into my label, and covered up the missing button holes with the label. I perforated the label to accommodate the eight buttons I was using, corresponding to the eight latched TTL outputs on the Tiny IR circuit. It almost looks like a commercial product and the next iteration would eliminate the imperfections. It is an excellent remote controller for my project, which is a wood fired pottery kiln, still in the design phase. Thanks for publishing an interesting magazine.

Keep up the great work!

Bob Colwell
via Internet

Dear Nuts and Volts:

I loved the article, "Making Friends with a Field Programmable Gate Array," by Chris Hannold (January 2004). Chris mentions having trouble programming the device in the Win XP environment. I had this trouble, but, when using Win 2000 for my XP system, I used the solution provided at the HVW Technologies website for the Altera device. The link to that information is **www.hvwtech.com/downloads/other/fpga_hardware_2000.pdf**

I hope this helps some of your other readers.

Andrew Cecil
Madison, AL

Dear Nut & Volts:

I read *Nuts & Volts* cover to cover each month. The Q & A column, by TJ Byers, is worth the price of the magazine alone. Could you find someone to do an article or even a small series similar to Ray Marston's excellent "Bipolar Transistor Cookbook," but based on using power MOSFETs?

I am particularly interested in motor control and high quality audio.

Jerold Schoof
Ardrossan AB, Canada

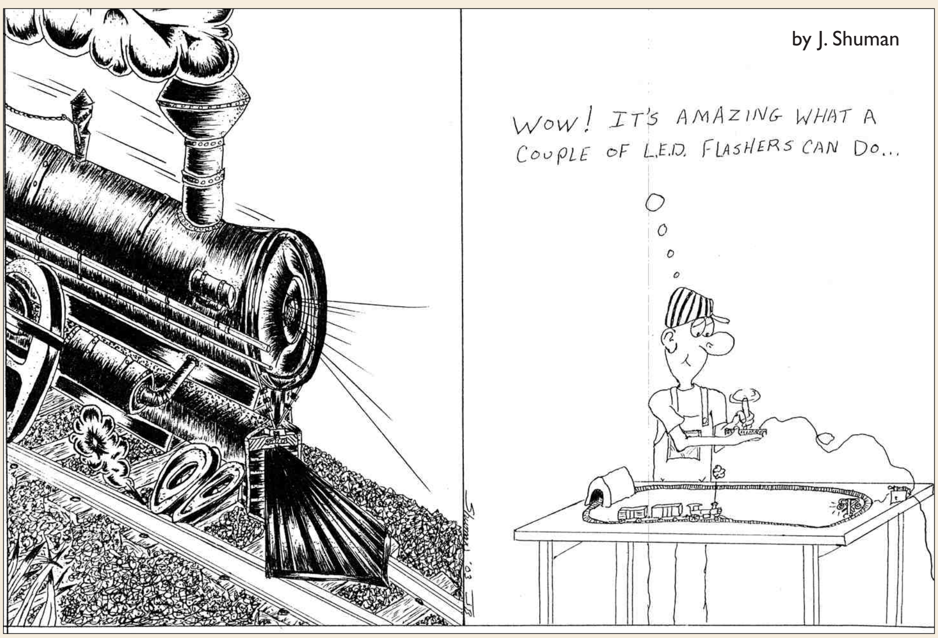
Dear Nuts and Volts:

I've been enjoying Ray Maston's "Bipolar Transistor Cookbook" as a good review of the basics. In Part 7 of the series (January 2004), the arrangement in Figure 16 jumped out at me. I see one serious problem there!

If the biasing arrangement is as shown — with no fixed resistors to the base of transistor Q1 — then, if the trimmer RV2 is set to the point where base and emitter are shorting out, the bias is completely removed from that transistor. Q1 cuts off completely, which means that Q3, Q4, Q5, and Q6 all go into hard saturation. R4, R5, R6, and R7 will at least get kind of warm and so will all four of those transistors.

I've seen this sort of thing happen in somewhat heavier-duty power amp circuits, usually as a result of something opening up in the bias string. The results aren't often pretty, sometimes letting the magic smoke out of some parts. The arrangement in Figure 12 — where there's a minimum resistance still in the circuit at all times — will probably be preferred.

Roy Tellason
via Internet



Errata

Author Thomas Henry, designer of the Clangora percussion synthesizer (November 2003), offers the following corrections to his project.

"On the parts placement guide (Figure 7, page 49), capacitor C38 should be labeled as C33. Both are 0.1 µF in any event. Also, resistor R20 mounts behind the front panel in addition to the components mentioned on page 50."

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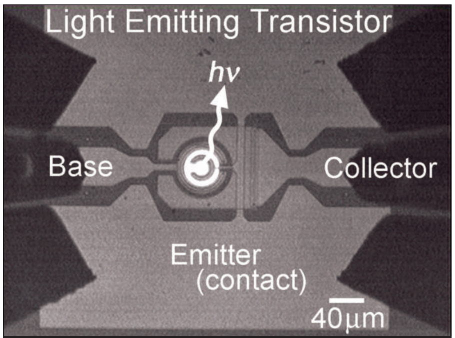
Advanced Technologies

Light-Emitting Transistor Promises Revolutionary Change



The newly discovered light-emitting transistor has three ports: input, electrical output, and optical output. Illustration courtesy of Walid Hafez, University of Illinois News Bureau.

There is a good chance that the names Nick Holonyak, Jr. and Milton Feng sound familiar. Holonyak invented the first practical light-emitting diode and the first semiconductor laser to operate in the visible spectrum; Feng is credited with creating the world's fastest bipolar transistor — a device that operates at a frequency of 509 GHz. Now, the two have collaborated at the University of Illinois at Urbana-Champaign (**www.uiuc.edu**) and, appropriately enough, have come up with a light-emitting transistor design that could turn the transistor into the fundamental element in optoelectronics, as it has in electronics.

"We have demonstrated light emission from the base layer of a heterojunction bipolar transistor and shown that the light intensity can be controlled by varying the base current," said Holonyak. "This work is still in the early stage, so it is not yet possible to say what all the applications will be, but a light-emitting transistor opens up a rich domain of integrated circuitry and high-speed signal processing that involves both electrical signals and optical signals."

A transistor usually has two ports: one for input and one for output. "Our new device has three ports: an input, an electrical output, and an optical output," detailed Feng. "This means that we can interconnect optical and electrical signals for display or communication purposes."

Unlike traditional transistors, which are built from silicon and germanium, the light-emitting transistors are made from indium gallium phosphide and gallium arsenide. "In a bipolar device, there are two kinds of injected carriers: negatively charged electrons and positively charged holes," Holonyak said. "Some of these carriers will recombine rapidly, supported by a base current that is essential for the normal transistor function."

The recombination process in indium gallium phosphide and gallium arsenide materials also creates infrared photons — the "light" in the researchers' light-emitting transistors. "In the past, this base current has been regarded as a waste current that generates unwanted heat," explained Holonyak. "We've shown that, for a certain type of transistor, the base current creates light that can be modulated at transistor speed."

Although the recombination process is the same as that which occurs in light-emitting diodes, the photons in light-emitting transistors are generated under higher-speed conditions. So far, the researchers have demonstrated the modulation of light emission in phase with a base current in transistors operating at a frequency of 1 MHz. Obtaining still higher speeds is considered certain.

"At such speeds, optical interconnects could replace electrical wiring between electronic components on a circuit board," Feng projected. This work could be the beginning of an era in which photons are directed around a chip in much the same fashion as electrons have been maneuvered on conventional chips.

Computers and Networking

Create Your Own P2P Network

A peer-to-peer (P2P) network, in case you are not up on the terminology, is simply a decentralized network in which all computers (clients) simultaneously act as client and server for all other clients, rather than making requests to the same specific central server.

Perhaps the most famous one (although not a pure P2P configuration) is Napster. Using software and the website of Foldershare (**www.foldershare.com**), you can now create your own P2P network, linking any number of computers in disparate locations. The software allows you to retrieve and update documents remotely, share files with other computers, and transmit files with the only size limit being your own available hard disk space and connection speed. You can even synchronize and update multiple copies of the same file across multiple computers. The basic process involves creating a library on your machine

and converting it into a group library. You then invite family, friends, and colleagues to share your library. They, in turn, create Foldershare libraries on their machines and these are available to everyone in the group.

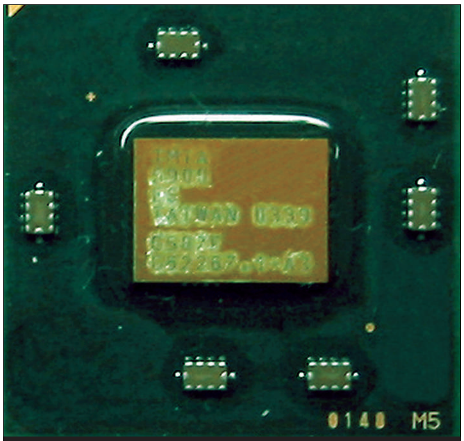
Features also include secure business networking, encrypted business-to-business (B2B) transfers, and automatic virtual private network (VPN) creation. To create your own network, just log onto the foldershare website and follow the directions. Best of all, the service (so far) is free of charge.

Bluetooth Adapter for Wireless Printing

A new Bluetooth adapter from Belkin (**www.belkin.com**) allows you to perform wireless printing from a desktop or laptop computer — or even a PDA — without the expense of buying a separate Bluetooth-enabled printer. Co-developed with Roving Networks (**www.roving networks.com**), the adapter adds Bluetooth technology to existing USB printers, allowing them to connect to any device enabled with Bluetooth v1.1 technology. The device offers a range of up to 100 meters, depending on the environment, number of users, and electromagnetic noise levels. Priced at about $100.00, it includes a printing utility for Pocket PC and Palm OS.

Bluetooth adapter allows wireless printing from a desktop or laptop computer. Photo courtesy of Belkin.

Ultra-Compact Microprocessor Introduced


Transmeta's Crusoe TM5700 and TM5900 microprocessors offer a 21 x 21 mm footprint and low power consumption. Photo courtesy of Transmeta Corp.

Transmeta Corporation recently introduced its Crusoe TM5700 and TM5900 microprocessors, designed for applications which

require high-performance processing within small and thermally constrained environments, including thin clients, blade servers, printers, copiers, point-of-sale terminals, smart displays, portable consumer devices, ultra-personal computers (UPCs), and set-top boxes. They are available in a 21 x 21 mm package for increased design flexibility; this package also enables smaller form factors for x86-compatible, energy efficient mobile and embedded computing.

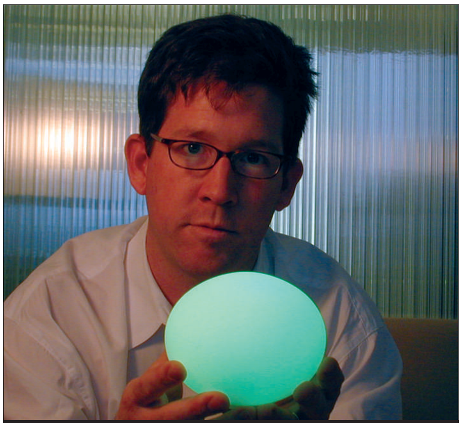
The TM5700 and TM5900 processors are a continuation of the Crusoe product line and provide the established low-power and high-performance characteristics of Crusoe's 128-bit VLIW (Very Long Instruction Word) engine, which issues up to four instructions per clock cycle. The Crusoe architecture includes integrated, on-chip Northbridge core logic, reducing both chip count and power requirements while decreasing the size and cost of the PC board. The new processors offer up to 1 GHz of x86-compatible performance and incorporate integer and floating-point execution units, separate 64 KB instruction and data caches, a large 512 KB (TM5900) or 256 KB (TM5700) L2 write-back cache, a 64-bit DDR SDRAM memory controller, and a 32-bit PCI controller.

Transmeta's LongRun® power management technology reduces thermal constraints by dynamically adjusting the operating voltage and clock frequency of the processor core, based on application demands; this is achieved by adapting processor operation to system thermal environments. Additionally, a small form factor Mini-ITX motherboard evaluation/reference platform, based on the TM5900 processor, will be available. This high-performance, low-power platform comes with schematics, design guides, processor specifications, device drivers, and all other requirements for evaluation and initiating product designs.

Circuits and Devices

Ambient Orb Provides Colorful Data Display

Yes, it looks like something out of a New Age gift shop and probably is the work of some lonely computer geeks who still live with their moms and wear Winnie the Pooh pajamas. Also, the company's claim that the device is intended to, "make the world calmer," is borderline hallucinatory. Yet, there is something intriguing about the Ambient Orb from Ambient Devices (**www.ambientdevices.com**).



President David Rose of Ambient Devices holds his glowing orb. Photo courtesy of Ambient Devices.

Basically, what you get for your $150.00 is a frosted glass ball that contains a bunch of LEDs and a pager. Data of your choosing is converted, configured, compressed, and transmitted to your orb via the national Ambient Information Network, after which, the information is presented in the form of color changes in the orb. Certainly, your computer does the same thing in a much more detailed manner, but that's the point — not all information needs to be presented in great detail.

At present, you can configure the orb to display things like changes in the Dow Jones or your personal stock portfolio, weather trends, traffic congestion, pollen count, number of Emails waiting

for you, public opinion poll results, and so on. Theoretically, it could also be set up to keep track of interest rates, available credit on a card, your blood alcohol level, or even the emotional state of your spouse (which may be directly related to your blood alcohol level).

Essentially, it can handle any information that can be fed into a network and the company claims that the device is compatible with existing long-range networks, as well as short-range (Bluetooth 802.11) ones. There are no monthly fees for the standard data channels, although some optional premium services involve a fee.

Is it a practical data output device or just a desktop toy? That probably depends on the application you choose. If you can think of a spectacular use for the technology, send your ideas to Ambient Devices. They are open to suggestions.

USB Cable for Confined Spaces

Okay, it's not exactly the most momentous achievement in electrical engineering history, but, if you need to install computer systems in confined spaces, you know that the somewhat inflexible nature of standard USB cables can be annoying. Even if you only need to shove your CPU closer to the wall without mangling the USB connector, take a look at the FlexUSB cable from Ideative, Inc. (**www.FlexUSB.com**).

The FlexUSB™ cable employs a flexible connector for use in confined spaces.

Introduced at the 2004 International Consumer Electronics Show in Las Vegas, NV, it utilizes less than half the footprint of traditional USB connectors and allows the cable direction to be set and locked in four different directions, eliminating the "loop-around" required by other cables. The device is USB 2.0 certified, comes with a one-year warranty, and works with all Windows and Mac computers and all USB devices. It is currently available in major retail stores in the US and 11 other countries.

Save Money with Surplus LEDs

If you use LEDs and are on a budget, it might be useful to visit **www.SurplusLED.com**, a website created late last year by LEDtronics (**www.led.net**) to sell off surplus products. SurplusLED.com was created to service a range of consumers, from purchasing agents to government procurement officials, who want to stretch their budgets in today's lean economic environment. The inventory changes daily and includes based LED lamps and bulbs, products for PC boards and displays, and discrete LEDs.

The products include 1.8 mm green round dome LED panel dots, red discrete cylindrical flat-top LEDs, rectangular bicolor LEDs, green diffused 5 mm square discrete LEDs, red T134 (5 mm) flangeless low-dome LEDs, discrete T1 (3 mm) bicolor dome LEDs, and some consumer LED products, such as LED flashlights, LED key chain lights, flashing LED safety vests, flashing mini emergency xenon strobes, and direct replacement 1157, 1156, 3157, and 3156 LED automotive tail/brake/turn signal lights. Payment can be made via PayPal for secure online transactions. Visa, American Express, Discover, and MasterCard are also accepted.

Industry and the Profession

18% Growth Forecast for Semi Industry in 2004

After several years in the doldrums, the semiconductor industry appears to be poised for a healthy growth rate of 18% this year, according to research firm IDC (**www.idc.com**). In a recent report, they wrote that, "Stronger than expected mobile phone and PC shipments have stabilized average sale prices and increased capacity utilization rates among suppliers. IDC expects that unit shipments will grow in double digits this year and next year for both mobile phones and PCs, which will drive a healthy growth cycle for over half of the semiconductor industry. From 2003 to 2008, IDC predicts that the semiconductor market will grow at a compound annual growth rate of 12%, rising from $160 billion in revenue this year to $282 billion in 2008."

Tadahiro Sekimoto to Receive Award

The Institute of Electrical and Electronics Engineers (IEEE, **www.ieee.org**) has named former NEC Chairman Tadahiro Sekimoto as recipient of the 2004 IEEE Medal of Honor. The award celebrates Sekimoto's, "pioneering contributions to digital satellite communications, promotion of information technology R&D, and corporate leadership in computers and communications." He is widely credited with turning NEC into a worldwide technical giant that excels in a wide spectrum of modern technology.

For more than 50 years, IEEE Life Fellow Sekimoto has been key to NEC's digital communications research efforts. At the frontier of digital technology, he designed early pulse-code modulation (PCM) equipment, as well as coding and decoding circuitry, in addition to contributing to the solution for network synchronization. His seminal work in digital and satellite communications formed the cornerstone for modern communications systems.

In the late 1960s, the challenge of how to use multiple satellites to provide service to many points around the world prompted Sekimoto to develop a time-division multiple access (TDMA) system and an automatic routing system. Not only did his work have a huge impact on satellite communications, but these technologies also formed a foundation for cellular telephony decades later.

The IEEE Medal of Honor, the highest award given by the IEEE, is bestowed upon individuals for their exceptional contributions or extraordinary careers in any IEEE field of interest. Sekimoto will receive the Medal at the annual IEEE Honors Ceremony in Kansas City, MO, in June 2004. **NV**

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Mean Well	PS-65-24	+24V@0-2.7A	**148646MC**	**33.95**
Artesyn	NLP150L-96Q5366	+3.3V@0.5+10A; +5.1V@1.5-2.0A; +12V@0-2A;+12V@0-0.65A	**219029MC**	**116.85**
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Mean Well	S-60-24	+24V@0-2.5A	85-264@47-63	**123351MC**	**57.95**
Mean Well	S-150-24	+24V@0-6.5A	88-132/176-264@47-63	**123449MC**	**76.95**
Mean Well	SP-300-24	+24V@0-12.5A	88-264@47-63	**137402MC**	**185.95**
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SC102TA1200-B02	+12@1500mA	2.9 x 2.0 x 2.6	UL/CUL	**210809MC**	**12.95**
DCR1205F12	+12@500mA	3.2 x 2.2 x 1.9	—	**162996MC**	**8.95**
DC1205F5	+12@500mA	2.5 x 2.1 x 1.7	UL/CSA	**102277MC**	**4.95**
41-2-15	+12@300mA	2.9 x 2.0 x 1.6	UL/CSA	**190043MC**	**4.49**

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P40A-3P2JU	40	+12@3.3A	100-240@50-60	5.5 x 2.3 x 1.5	**155213MC**	**34.95**
SPU50-3	60	+12@5.0A	100-240@47-63	5.6 x 2.9 x 1.5	**155230MC**	**49.95**
KWM12F-P2MU	18	+12@1.5A	100-240@47-63	4.0 x 1.9 x 1.5	**216531MC**	**26.95**
P40A6P2J	40	+24@1.66A	100-240@50-60	4.1 x 2.6 x 1.4	**181884MC**	**33.95**

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NMB	3110KL-04W-B10	12	25	25	3.15 x 3.15 x 1.00	**131748MC**	**7.95**
Sunon	KD1204PFB2-8	12	6.3	30	1.60 x 1.60 x 0.40	**161699MC**	**7.95**
Sunon	KD1212PMB1-6A	12	108	42	4.68 x 4.68 x 1.50	**94625MC**	**11.95**
Sunon	KD0504PFB2-8	5	5.5	23	1.60 x 1.60 x 0.40	**196373MC**	**8.49**

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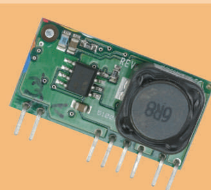

219150MC

ARTESYN TECHNOLOGIES

Mfr.	Mfr. Cross Reference No.	Power (W)	Output Rating (Volts@Current)	Input Range	Jameco Part No.	Price
Mean Well	SCW03A-05	3.0	+5V@600mA	9-18V	**213268MC**	**$15.49**
Mean Well	SD-25A-24	26.4	+24@1100mA	9-18V	**175812MC**	**40.95**
Mean Well	SKE15A-05	15.0	+5V@3000mA	9-18V	**155715MC**	**34.95**
Artesyn	SIL06C-05SADJ-V	20.0	+0.9-3.3V@6	4.5-5.5V	**219150MC**	**12.35**
Astec	AA9090A	21.0	+5.1V@3750mA; +12.6V@100mA; -26V@40mA	0-20V	**109276MC**	**6.95**

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- 5-50 MM Zoom
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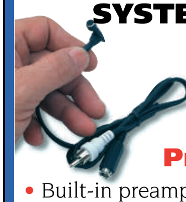

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Basics For Beginners

Just For Starters

Interface Choices — Part 1: Transistors

There are many projects where a control circuit drives or senses external or high-current signals. Control circuits are typically constructed with digital or analog integrated circuits (ICs) that have relatively low drive strengths. TTL and CMOS ICs are capable of driving a range from several hundred microamps to several milliamps. Such drive strengths may suffice for one or two small LEDs, but what about light bulbs, AC-powered a ppliances, and motors? What about situations where safety or noise concerns prohibit directly connecting the control circuit to a load being driven?

Many projects require a partial or complete isolation between a control circuit and its input/output signals. Fortunately, there are numerous solutions to this problem. Selecting an appropriate scheme depends on the type of isolation required. This month's column discusses transistor-based isolation techniques for DC control signals, as compared to analog signals such as audio or video. DC isolation requires only the transmission of an on/off state from one circuit to another. Next month's column continues the discussion with other isolation techniques.

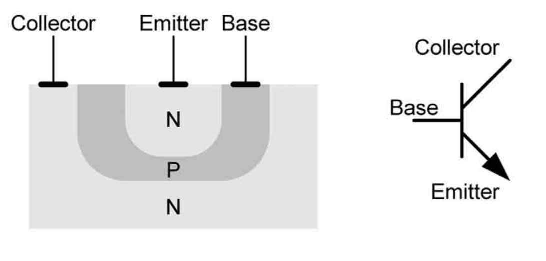
Transistors

The first question to ask is whether true isolation or merely amplification is required. If you want to turn on a light bulb or drive a DC motor, control signal amplification may be all that is warranted. A few tests to verify if this is the case include:

- Is the load DC?
- Does the load share a common ground with the control circuit?
- Is the load safe enough to not cause a damaging voltage surge on the control signal?
- Is the control circuit immune to electrical noise that may emanate from the load?

If the answer to all of these questions is yes, transistors may be most appropriate for driving the load. Transistors are solid-state amplifiers that enable a small control current to modulate the flow of a much larger current. There are several basic types of transistors. We will use bipolar junction transistors (BJTs) in this discussion because they are commonly available and easy to work with. Let's begin with a brief review of BJT operation.

Figure 1. The NPN BJT structure and its electrical symbol.



NPN BJTs

BJTs are manufactured in two varieties: NPN and PNP. NPN and PNP refer to the stacking of positively and negatively doped silicon. Each variety behaves similarly, but with opposite polarities. To keep things simple, we can use NPN BJTs as our working example. A more complete discussion of transistor usage and operation can be found in my book, *Complete Digital Design*. Figure 1 shows the basic silicon structure of an NPN BJT and its corresponding symbol in a circuit diagram. The three contacts on a BJT are the base, emitter, and collector. When a sufficient voltage is applied to the base-emitter junction, a large current may flow from collector to emitter. This voltage is approximately 0.7 V, the forward voltage of a silicon diode. (The base-emitter junction forms a diode because P-N silicon junctions naturally form diodes.)

Figure 2 shows the basic hookup scheme for using an NPN BJT in a digital, or DC, amplification role. BJTs are also capable of AC amplification, where the load is driven with a higher amplitude version of the input signal; however, we are dealing with the DC amplification required by typical high-current loads. The emitter is grounded to establish a ground return path for the control signal and the high-current load. The base is connected to the control signal driver through a current limiting resistor, R_B.

The Base Resistor

A current limiting resistor is required to protect the transistor and the driver. The base-emitter junction has no inherent mechanism for limiting the current flowing through it. Yet, the junction tries to maintain approximately 0.7 V across it. So, what happens if you connect a 5 V battery to the base? The base will draw as much current as it can until the voltage falls below 0.7 V. In most situations, the transistor will lose this battle and simply overheat to the point of destruction. A current limiting resistor ensures that the base voltage can be safely maintained at the silicon's natural 0.7 V threshold. Any excess voltage is dropped across the resistor.

Selecting R_B can be done with varying degrees of accuracy, depending on how much current you are trying to drive. BJTs relate the current flowing into the base and collector through a constant called beta, ß (many transistor manufacturers refer to ß as hFE). The collector current, I_C, may not exceed the product of ß and the base current, I_B. Put more succinctly: $I_C = ßI_B$. Despite ß effects, the circuit may further restrict the collector (load) current. Beta varies with the specific transistor. A common value is ß = 100.

Many situations allow a rough selection process for R_B. Let's say that you have a 74LS-type TTL driver. When the driver goes high (greater than about 2.7 V), the transistor will turn on because the base will be brought from low (0 V) to high. The 74LS family is specified with about 0.4 mA maximum high-level drive strength. We can pick R_B to use all of that current to provide maximum load current.

First, we calculate the voltage drop across the resistor as the difference between the driver output voltage (2.7 V) and the base-emitter junction voltage (0.7 V), which is 2 V. Now, using Ohm's law (V = IR), we find that 2 V divided by 0.4 mA gives a resistance of 5KΩ. The standard resistance value 4.7KΩ is good enough. That's it. You can pick a different value if you are using a CMOS driver with higher output voltage and current.

At this point, the circuit in Figure 2 is capable of sinking up to 40 mA ($IC = ßI_B$ = 100 x 0.4 mA) of load current. Depending on the load's characteristics, you may place a current limiting resistor between the load and collector, as well.

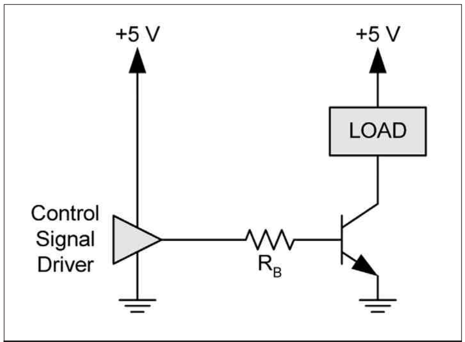


Figure 2. Basic digital amplification with an NPN BJT.

Maintaining Operation

One thing to keep in mind is the minimum permissible collector voltage. A typical saturation voltage between collector and emitter is 0.3 V. In our circuit, the emitter is at ground (0 V), so the saturation voltage is 0.3 V. If the collector falls below 0.3 V, the transistor will no longer conduct. You must ensure that the load can operate in the voltage difference between the saturation voltage (0.3 V) and the power rail.

If the circuit is supplied with 5 V, the allowable voltage difference is 4.7 V. If the load needs higher voltage, you may introduce a higher supply voltage, such as 12 V. Keep in mind that the control circuit and load power supplies must share a common ground connected to the emitter.

Higher Load Currents

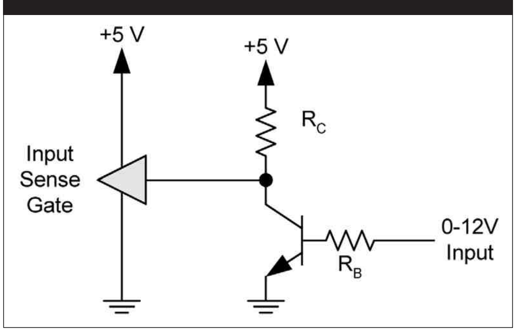
Transistors with higher ß are available to provide more collector current. Yet, a single BJT eventually runs out of steam as higher load currents are desired. Multiple transistors may be cascaded in various topologies, such as a Darlington pair to increase the final load current. These circuits are outside the scope of this article.

What About Inputs?

So far, we've covered only control outputs. Inputs work similarly, but the base is driven by the external circuit being sensed. A transistor is useful in an input sensing circuit if the external signal falls outside the control circuit's specifications. Typical digital ICs restrict the logic input levels to be within a diode drop of the IC's voltage rails. If an IC runs on a 5 V supply, the legal input range might be -0.7 to +5.7 V. Manufacturers may further restrict this range to prevent damage to the IC.

Figure 3 shows an NPN BJT used in an input sensing circuit. Here, we assume that the input circuit ranges from 0 to 12 V. The input may be a hazard alarm or other sensor that operates on a higher voltage. A 12 V input is outside the legal range for practically all logic ICs. We first select a current-limiting base resistor, R_B, to provide a safe base current, I_B. The voltage across R_B is known — the input (12 V) minus the base-emitter junction voltage (0.7 V) is 11.3 V. A wide range of resistances is acceptable for this application. 10KΩ yields I_B = 1.13 mA. Even 100KΩ gives an acceptable I_B = 0.113 mA. Keep in mind that the transistor only has to drive a logic input, so very little col-

Figure 3. A BJT in an input-sensing role.



lector current is required. This takes care of the design work at the "dirty" side of the circuit. On the control, or clean, side of the circuit, we have to connect the control input to the transistor so that legal voltage levels are generated for high and low logic levels. The low voltage level is determined for us by the transistor's saturation voltage, about 0.3 V, which is well within the typical 74LS specification. The high voltage level is also determined — this time by the control circuit's voltage supply (5 V, in this example). So, the remaining design point is selecting a value for the collector resistor, RC. Choosing RC is a compromise and there is no single correct answer. A higher resistance reduces power consumption because less collector current, IC, is required to pull the collector down to 0.3 V. A lower resistance more rapidly pulls the collector up to 5 V when the transistor turns off. The compromise is between power consumption and signal rise time. A good place to start is selecting RC = 4.7KΩ, corresponding to IC = 1 mA. 4.7KΩ should give a fast enough rise time. If not, 3.3KΩ, 2.2KΩ, or lower values can be used.

Logical Inversion

It is important to realize that the input sensing circuit performs a logical inversion function. When the external signal is low (0 V), the transistor is off. Therefore, no collector current flows and RC pulls the logic input high (5 V). When the external signal is high (12 V), the transistor conducts current through RC and the logic input is pulled low (0.3 V). This should not be a problem, but it must be compensated for. If the external event is deemed active when the signal is at 12 V, the control input should regard an active state as logic-low.

Negative Input Levels

The input circuit can also operate and protect the control circuit from negative input levels. If a negative voltage is applied to the BJT's base, the transistor will not conduct. The transistor does not translate a negative base voltage to a negative collector voltage. However, a transistor does have physical limits. Be sure to check the manufacturer's data sheet for the maximum allowable voltage from emitter to base, which is typically in the order of several volts.

Transistor Usage Qualifications

Four qualifiers were listed earlier for whether a transistor is an appropriate isolator. Let's review them with an understanding of BJT basics in mind. First, the load has to be DC because the transistor circuit cannot handle an AC power signal. Second, the transistor has a common emitter terminal and, therefore, both the driver and load must share that common ground. Third, the transistor can break down under high-amplitude voltage surges. Fourth, load noise (e.g. motor noise) can pass from the collector to the base. Many interface problems can be solved with transistors. Transistors are compact and reliable devices. Yet, other options are available when transistors are deemed unsuitable for a particular interfacing task. In next month's column, we will discuss how optoisolators and relays pick up where transistors leave off. **NV**

About the Author

Mark Balch is the author of *Complete Digital Design* (see **www.completedigitaldesign.com**) and works in the Silicon Valley high-tech industry. His responsibilities have included PCB, FPGA, and ASIC design. Mark has designed products in the fields of telecommunications, HDTV, consumer electronics, and industrial computers. In addition to his work in product design, Mark has actively participated in industry standards committees and has presented work at technical conferences. Mark holds a bachelor's degree in electrical engineering from The Cooper Union in New York City. He can be reached via Email at **mark@completedigitaldesign.com**

Micro Memories

Bulletin Board Systems: Before There Was a World Wide Web

In 1978, the Internet existed, but it was still largely restricted to universities and the military (and still called Arpanet.) It was only a year before that Hayes had released the first modem for PCs. While CompuServe (see the October 2003 "Micro Memories") and the Source were positioning themselves as national online services, Ward Christianson and Randy Suess of Chicago had another idea for connecting groups of users to computers: the bulletin board systems or BBS.

Christianson and Suess began trying to build a personal computer version of the large mainframes that they had previously logged onto.

In 1977, Christianson wrote Xmodem, the first computer program used to transfer files between computers equipped with modems. The next year, he teamed with Seuss to create the first BBS software.

While early modems were built primarily to allow personal computer owners to log onto mainframes, they also had the ability to be accessed themselves, giving others the option of logging onto that personal computer.

The genius of Christianson and Suess was in their effort to allow the information on one computer to be shared in a coherent, logical fashion, modeled after the proverbial town bulletin board. So, depending upon the nature of the BBS, users could dial-in, log-on, and exchange computer information, movie reviews, sporting news, etc. Most BBS were free, but a few charged membership fees or kept their virtual doors open through selling products to their members.

In an April 1980 interview with *Kilobaud Microcomputing Magazine*, (reprinted at **www.portcommodore.com/commodore/bbs/cbbs.html**) the Chicago-based Christianson and Suess seemed somewhat surprised by how popular their pioneering BBS had become.

They reported getting calls from as far away as Hawaii, Australia, and Europe, with the average user (no matter where he was located) connecting for 20 minutes a pop.

Eventually, Christianson and Suess began selling their software at $50.00 a copy, though they admitted at the time that they had little hope of turning a profit.

Not surprisingly, other entrepreneurs arrived on the scene once they saw the viability (not to mention the actual idea!) of BBS software.

The 1980s: BBS' Heyday

While there weren't any $399 .00 eMachines or package deals that

Many early BBS ran on Apple IIs and provided information for their users.

The Commodore Pet was a late 1970s and early 1980s PC that competed with the Apple II and TRS-80.

The IBM PC was introduced in 1981 and became one of the dominant PC designs of the 1980s.

would throw in a free computer with a subscription to an online service in the 1980s, the decade would turn out to be the golden era of BBS. Personal computers and modems did become more affordable than their predecessors of the previous decade, as did telephone connectivity charges.

PCs took off in popularity contemporaneously to the *Dungeons & Dragons* phenomenon. So, it's not surprising that there were plenty of BBS geared towards role-playing games, where each post was a new move in a campaign.

As early as 1981, there were already adult-oriented BBS. Other than ASCII art, there wasn't much in the way of graphics, but there was plenty of verbal porn and even a few products for sale.

In 1983, a John Deere employee named Bob Mahoney started a single-line BBS on an IBM PC in his Wisconsin apartment during Thanksgiving weekend, with the goal of offering software programs and advice to business people. His BBS, which he dubbed Exec-PC, became one of the earliest fee-based bulletin boards.

Within a year, Mahoney added a second line so that callers didn't get a busy signal. By 1985, he had six lines and 280 Mbytes of file storage; his wife began managing the business side of the system. According to the September/October 1994 issue of *Wired*, Mahoney found that callers were willing to pay a modest $60.00 per year subscription fee to have access to lots of files. They also liked not having to deal with the constant busy signals they got when dialing single-line bulletin boards.

By the time their *Wired* profile hit the newsstands, Exec-PC featured 250 telephone lines and 24 Gigabytes of file storage. It received 4,500 calls a day from a user base that was downloading about 750,000 files a month. The $75.00 user fee from each member resulted in an annual gross income of almost two million dollars. After expenses, Mahoney could more than afford to indulge his hobby: racing automobiles.

A Glimpse of the Future

However, the early 1990s development of a graphical interface, which made the Internet user-friendly, would signal the eventual end to the vast majority of regional, dial-in bulletin boards. (Eventually, for a large percentage of online users, dialing-in itself would become an increasingly quaint term.)

For example, by 1998, with the Internet boom in full force, Bob Mahoney transferred his early experience and the Exec-PC name to an extremely popular regional Midwest ISP. He closed his BBS in 1999.

In 1992, John Dvorak awarded one of his Annual Dvorak PC Telecomm-unications Excellence Awards to Suess and Christianson for their development of the BBS.

The Imsai 8080 was a clone of the Altair 8800. Both were used by many early BBS subscribers to go online in the late 1970s.

Dvorak presented his Lifetime Achievement Award to Christianson, "for outstanding contributions to PC telecommunications, including the development of the public domain Xmodem file transfer protocol, the first protocol widely used with personal computers."

Today, the two run a web-based version of their original BBS at **www.chinet.com**

If online providers — such as CompuServe and AOL — proved the viability of the Internet among everyday consumers, then BBS gave us an early glimpse of individually owned websites and online forums, their ability to reflect the personalities and idiosyncrasies of their owners, and that user-created content could be an inviting alternative to mass media.

For that alone, we should be grateful. **NV**

The Altair 8800 was one of the first personal computers. It could connect to a BBS via an external modem.

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- ✔ Line level inputs and output
- ✔ All new design, using SMT technology

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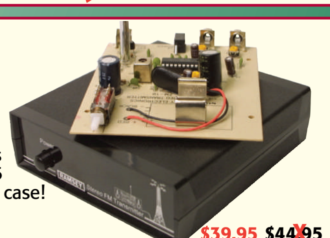
FM25B	**Professional Synthesized FM Stereo Transmitter Kit**	$119.95	~~$139.95~~

WOW!! SAVE!!

Tunable FM Stereo Transmitter



- ✔ Tunable throughout the FM band, 88-108 MHz
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FM10C	**Tunable FM Stereo Transmitter Kit**	$39.95	~~$44.95~~
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WOW!! SAVE!!

Professional Synthesized AM Transmitter

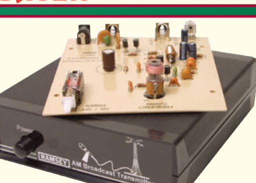
- ✔ Fully frequency synthesized, no frequency drift!
- ✔ Ideal for schools
- ✔ Microprocessor controlled

Run your own radio station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area. It is widely used by schools - standard output is 100 mW, with range up to ¼ mile, but is jumper settable for higher output where regulations allow. Broadcast frequency is easily set with dip-switches and is stable without drifting. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply!

AM25	**Professional Synthesized AM Transmitter Kit**	$89.95	~~$99.95~~

WOW!! SAVE!!

Tunable AM Transmitter



- ✔ Tunes the entire 550-1600 KHz AM band
- ✔ 100 mW output, operates on 9-12 VDC
- ✔ Line level input with RCA connector

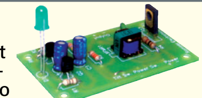
A great first kit, and a really neat AM transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! One of the most popular kits for schools and scouts! Includes matching case for a finished look!

AM1C	**Tunable AM Radio Transmitter Kit**	$29.95	~~$34.95~~
AC125	**110VAC Power Supply for AM1**		$9.95

WOW!! SAVE!!

Mini-Kits...
Great Starters!

Tickle-Stick



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC

TS4 **Tickle Stick Kit** **$12.95**

Super Snoop Amplifier

Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output. Makes a great "big ear" microphone. Runs on 6-15 VDC

BN9 **Super Snoop Amp Kit** **$9.95**

Dripping Faucet

Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Runs on 4-9 VDC.

EDF1 **Dripping Faucet Kit** **$9.95**

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BL1 **LED Blinky Kit** **$7.95**

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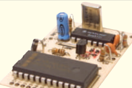

Strappable to detect any single DTMF digit. Provides a closure to ground up to 20mA. Connect to any speaker, detector or even a phone line. Runs on 5 VDC.

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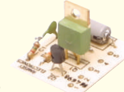
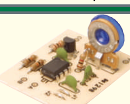


Produces the upward and downward wail of a police siren. Produces 5W output, and will drive any speaker! Runs on 6-12 VDC.

SM3 **Electronic Siren Kit** **$7.95**

Universal Timer



Build anything from a time delay to an audio oscillator using the versatile 555 timer chip! Comes with lots of application ideas. Runs on 5-15 VDC.

UT5 **Universal Timer Kit** **$9.95**

Voice Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch, or to turn on a recorder or light! Runs on 6-12 VDC and drives a 100 mA load.

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Electronic Theories and Applications From A to Z

Let's Get Technical

Controlling the Light: Hardware and Software Protocols for the Fiber Communication Systems

Last time, we examined the basic operation of the simple fiber optic communication system shown in Figure 1. We saw that six data bits were packed into an 8-bit frame, with transmitter and receiver circuits on each end providing the parallel-to-serial and serial-to-parallel conversions.

This month, I will show the details behind the transmitter and receiver circuits and explain how a software protocol is used to transmit eight bits of data.

Before we examine the transmitter and receiver hardware, let us review the format of the 8-bit transmission frame that is exchanged between the transmitter and receiver. Figure 2 shows the frame format.

The format of the transmission frame (Start bit, D0 through D5, Stop bit) represents a hardware protocol. This protocol must be used at both ends of the communication link for reliable data transfer. The receiver must expect the same frame format or the frame bits will be interpreted differently at the receiver. Who knows what problems might occur as a result of this?

Since this is an asynchronous communication system (no clock transmitted with the data), we must use the Start and Stop bits as framing bits to assist in synchronization between the transmitter and receiver. We shall soon see that the falling edge of the Start bit sets the receiving machinery in motion. Figure 3 shows the schematic diagram of the transmitter. Table 1 explains the input/output signals.

Figure 2. A transmission frame.

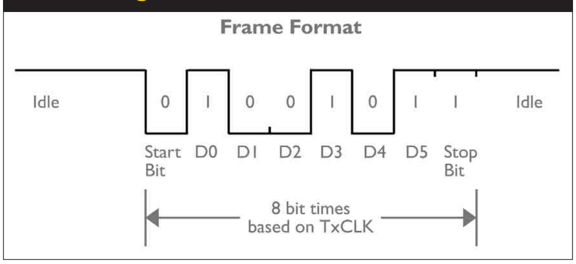
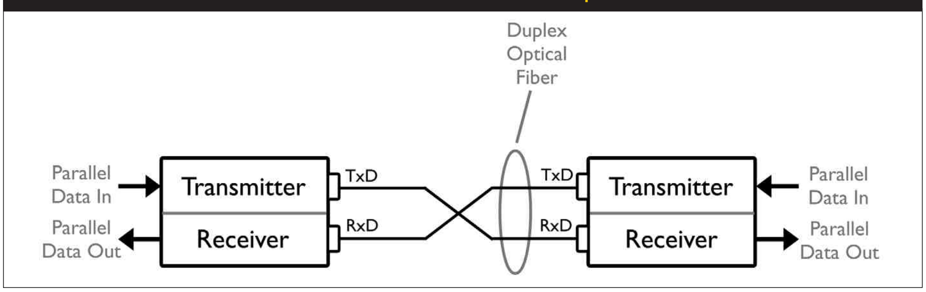


Figure 1. Fiber optic communication link allowing full-duplex communication between endpoints.



An 8-bit shift register is parallel loaded (via the LOAD input) with the six bits of frame data to transmit, along with hard-wired start (0) and stop (1) bits. Bits are clocked out at a rate determined by TxCLK. When the WR input clocks the D flip flop, the Q-not output goes low, allowing the 4-bit counter to begin counting and changing the state of TxRDY. After eight bits have been clocked out, the output of the inverter goes low, clearing the flip flop, which, in turn, clears the counter. When the counter output goes to 0000, the OR gate allows the shift register to be loaded with new data.

Figure 4 illustrates the receiver circuitry; its input/output signals are described in Table 2.

Unlike the transmitter, the receiver uses an RxCLK clock that is 16 times faster than the incoming bit rate. This allows the bit stream to be sampled in the middle of each bit for higher accuracy and helps eliminate timing problems due to the slight difference in clock frequencies on each end of the communication link.

A falling edge on the RxD input clocks a one through the first D flip flop, allowing both counters to begin counting. After the first eight RxCLK pulses, the second counter gets clocked once. This causes the start bit to get loaded into the 8-bit receiving shift register. Then, every 16 RxCLK pulses, the second counter is clocked again and another bit is loaded into the shift register. After

eight bits have been received, the inverter resets the first flip flop (stopping the counters) and sets the second flip flop, indicating that a character has been received via the RxRDY output. A latch on the output of the shift register can be used to buffer the received character, allowing the reception of a second character to begin immediately.

With the transmitter and receiver speaking to each other, we now face the final hurdle: How can eight bits of data be transmitted with the existing frame format? The answer is: They cannot. So, we will use more than two frames. In fact, a three-frame sequence is used to transmit an 8-bit data value. Examine Table 3 before continuing.

The six bits available in a frame are divided into two groups: a control-bit group and a data-bit group. Bits D5 and D4 make up the 2-bit control group. Since there are four different patterns possible with two bits (00,

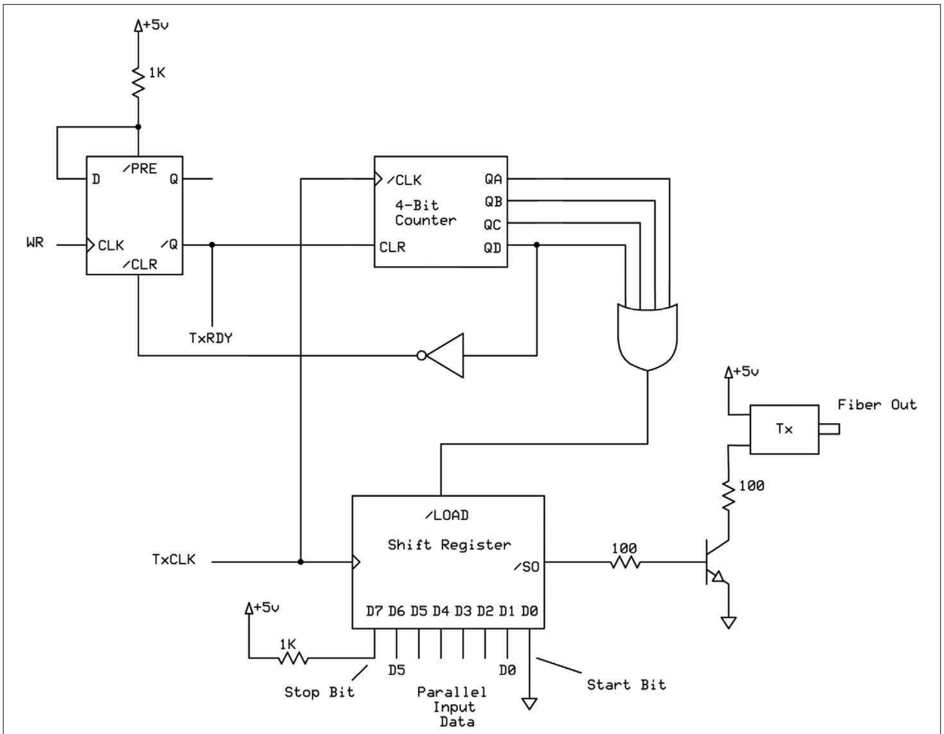


Figure 3. Fiber optic transmitter circuit.

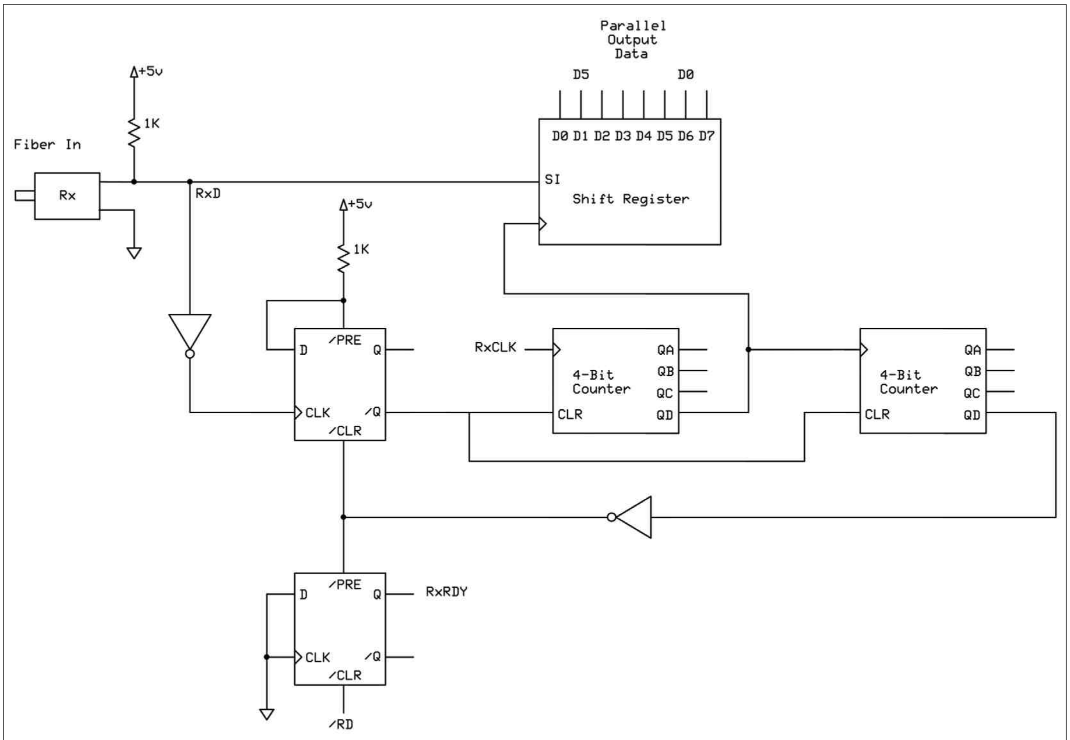


Figure 4. Fiber optic receiver circuit.

01, 10, and 11), we get four frame types by assigning D5 and D4 appropriately. The four bits in the data group carry any of the following:

- The lower four bits of a data byte (D0 through D3)
- The upper four bits of a data byte (D4 through D7)
- Four Address bits (to point to a destination station)
- Four Reserved bits

This organization of the six frame bits is a software protocol. Both ends of the communication link must agree on how the six bits are interpreted for proper communication. Now, to send eight bits of data from one station to another, one of the following sequences must be used:

- A, LN, UN (little endian format)
- A, UN, LN (big endian format)

The ADR frame contains the address of the destination station that will be receiving the LN and UN frames. Note that 16 addresses are possible, since there are four address bits in the ADR frame. Patterns 0000 (0) through 1110 (14) are assigned as unique station addresses. Address 1111 (15) is a broadcast address; all stations will receive the data when this address is used. Note that the three frame sequences are yet another layer of software protocol, higher than the previous one that defined the bit groups and frame types. This layer shows how the frames are used to convey information.

With the TxCLK running at 1.25 MHz, the bit rate over the fiber link will be 1.25 Mbps. Dividing by eight gives us 156,250 frames/second. Dividing this result by three gives us 52,083 frame groups (ADR, LN, UN) or the ability to transmit 52,083 eight-bit data values end-to-end. As an application, this would support six simultaneous digital channels of 64 Kbps each over the fiber link. Each 64 Kbps channel could represent a digitized telephone conversation (8,000 eight-bit samples/second is the phone company sampling standard).

An old professor of mine once said, "First, make it work. Then, make it pretty." What can we do to pretty up the transmitter and receiver circuits? For one, we could add error detection

Table 1. Transmitter circuit input/output signals.	
Input/Output Signal	Signal description
D0 - D5	Parallel input data. D0 is the LSB and is transmitted first (after Start bit).
WR	Write. This input signal initiates a transmission.
TxCLK	Transmitter clock. A bit is clocked out of the transmitter with each TxCLK cycle.
TxRDY	Transmitter ready. This indicates the transmitter is ready to begin a new transmission.

Table 2. Receiver circuit input/output signals.	
Input/Output Signal	Signal description
D0 - D5	Parallel input data. D0 is the LSB and is received first (after Start bit).
RD	Read. This input signal indicates that parallel data has been read from the latch and resets the RxRDY signal.
RxCLK	Receiver clock. A bit is clocked into the receiver every 16 RxCLK cycles.
RxRDY	Receiver ready. This output signal indicates the reception of a new frame.

Table 3. Frame types and descriptions.

D5-D4-D3-D2-D1-D0	Frame Type	Description
0-0-D3-D2-D1-D0	LN: Lower Nybble	Frame carries the lower four bits of data byte.
0-1-D7-D6-D5-D4	UN: Upper Nybble	Frame carries the upper four bits of data byte.
1-0-A3-A2-A1-A0	ADR: Address	Frame carries the address of a destination station.
1-1-R3-R2-R1-R0	RES: Reserved	Reserved control frame.

and correction. This would require the addition of at least one parity bit to the frame format. One parity bit can only detect errors, not correct them; two or more parity bits are required for error detection and correction.

For example, four parity bits added to eight bits of data allow us to detect and correct all single bit errors. So, we must add a parity generator to the transmitter and a parity checker to the receiver. It is also possible to add the error detection and correction at a higher protocol layer, using software instead of hardware. For example, we could require that an ACK (acknowledgement) frame be returned after each frame group (ADR, LN, UN) has been received.

We may also improve the performance of the fiber communication system by employing digital data compression. For a system such as this, the cost of the compression circuitry would be far more than the cost of the simple transmitter and receiver circuits. Compression may also be preformed at a higher layer, using software.

For instance, suppose you know in advance that your data is populated with many patterns that look like this: 00000000 and 11111111. In this case, you may want to use two of the Reserved frame types to represent each pattern. For example, let Reserved frame 110000 code the 00000000 pattern and 111111 code the 11111111 pattern. Now, a special two-frame group is created to carry the "compressed" patterns. Thus, we have (ADR, CPAT1) and (ADR, CPAT2) representing our compressed patterns, with CPAT1 and CPAT2 being the symbolic names of the 110000 and 111111 Reserved frames. Using one of these groups saves us the time of one frame — a savings of eight bits of bandwidth (ADR, CPAT versus ADR, LN, UN). If there are many patterns that look like 00000000 or 11111111 in the original data, a good savings in total transmission time (or bandwidth) will result.

So, we have seen that a digital fiber optic communication system is a combination of hardware and software, with protocols established that allow each end of the communication link to interface properly with each other. Next time, I will show a different fiber application, called the Fiber Optic Ring Oscillator, whose frequency of oscillation is directly dependent on the speed of light in the fiber. **NV**

About the Author

James Antonakos is a Professor in the Departments of Electrical Engineering Technology and Computer Studies at Broome Community College, with over 27 years of experience designing digital and analog circuitry and developing software. He is also the author of numerous textbooks on microprocessors, programming, and microcomputer systems. You may reach him at antonakos_j@sunybroome.edu or visit his website at **www.sunybroome.edu/~antonakos_j**

Electronics Q&A

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, as well as comments and suggestions.

You can reach me at: **TJBYERS@aol.com**.

What's Up:

How capacitors work and how to add life to aging electrolytics. Two PC power supply solutions, an MCU power interface, and LED mood lights. A nifty reader circuit and two schematic corrections from January 2004.

Basic Electronics 101: Capacitance

Q. This may fit in the category of a foolish question, but I have been curious about it for some time. Assume a capacitor is made up of two plates separated by a given distance. Add a significant charge, then disconnect the power source. Now, physically separate the plates. What happens to the charge?

John S. Young
Scottsdale, AZ

A. It's not a foolish question and I'll bet most readers can't answer it. When voltage is first applied to the plates, the charge isn't immediately transferred to the capacitor. Instead, work has to be done to get the charge on the plates (I'll spare you the math!) — work that is measured in Joules. When you physically separate the plates, you add work. The result is added energy to the capacitor and extra charge. In other words, you end up with more charge and voltage than before. Let's see what else happens at the same time — refer to Figure 1.

Capacitance, on the other hand, decreases. That's because capacitance is inversely related to the distance between the plates, is directly proportional to the area of the plates, and isn't a factor of charge.

What happens if you keep the battery attached when you separate the plates? Contrary to what you may think, the charge in the capacitor decreases. Why? Because the battery holds the voltage across the capacitor constant, so, as you push the plates apart and add work, the charge has to decrease to satisfy Coulomb's Law. In effect, you are pushing current back into the battery with your physical action. As before, the capacitance decreases because of the increased separation of the plates. I guess some things never change.

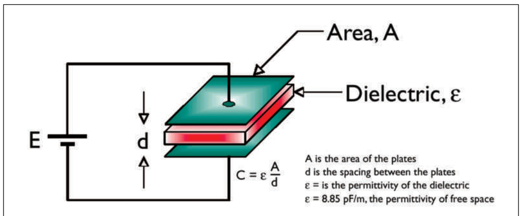


Figure 1

HGH for Old Electrolytics

Q. I recently took a box of Mallory 6000 µF/60 V capacitors out of storage, where they have been sitting around for about 15 years. I would like to use them in an upcoming audio amplifier project, but have concerns about the health of these electrolytics. Can I use my variable power supply to "reform" the caps or is there a circuit I can build that will restore these caps to their former glory?

Henry S. Wypa
Rose City, MI

A. Electrolytics use a very thin film of oxide on the positive electrode that serves as the dielectric between the plates; the oxide needs a small leakage current to keep the film in place. If left unpowered for long periods of time, the oxide layer can break down, making the capacitor into more or less a dead short. If power is applied to a capacitor in this condition, the leakage current can be excessive enough to cause the cap to overheat and possibly even explode.

Reforming applies voltage to the capacitor in a controlled manner, so, if there is a short,

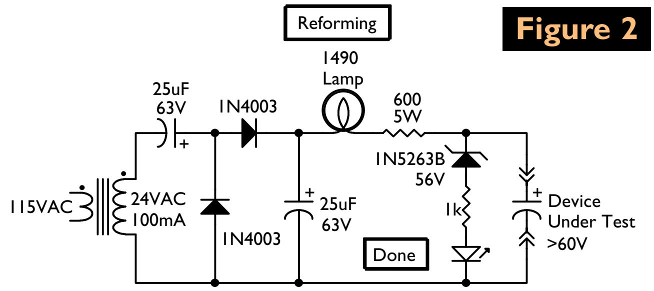


Figure 2

Electrolytic Capacitor Reformer

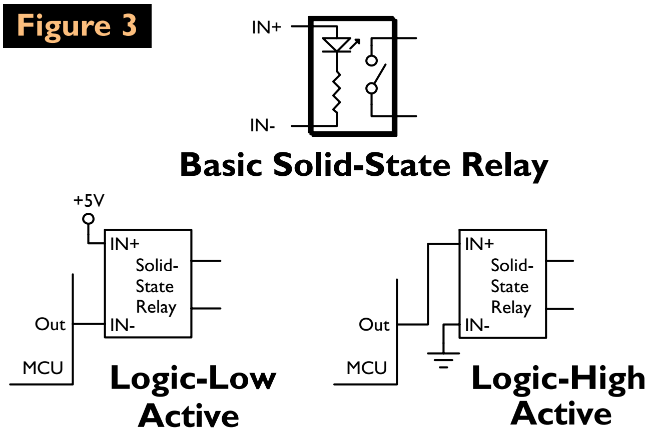


Figure 3

the current is limited to a safe level. This allows the oxide layer to reform slowly, without producing excessive heat and gases. While you can ride hard on your variable power supply to reform an electrolytic, it's a very time-consuming task. Reforming can take up to several hours. A better solution is the reformer circuit shown in Figure 2.

A 24 volt wall-wart and voltage doubler provide the 60 volts needed to reform the electrolytic. The 600 ohm resistor limits the reforming current to 100 mA, an acceptable level for caps of this size. If you can't find a 600 ohm, 5 W resistor, one can be made by stringing six 100 ohm, 1 W resistors together in series. (You can reduce the reforming current for lower capacitance values by increasing the resistance. The acceptable leakage limit can be calculated from A = 0.01CV, where C = capacitance in µF, V = applied voltage in volts, and A = the leakage current in mA.) When current flows through the cap, the "reforming" lamp will light. As the capacitor gets up to snuff and is able to hold a charge, the lamp goes off (current ceases to flow) and the "done" LED lights.

SSR Meets MCU

Q. I am building a microprocessor-based environmental control system for a wine storage room. It is designed around the Maxim/Dallas 1-Wire line of products (including the DS18S20-PAR digital temperature sensor and DS2405 addressable switch) and I have a fairly good grasp of the digital side of the system, as in having the right 1s and 0s show up at the right times and in the right places.

However, I am not sure of the best way to use those logic levels to actually turn something on, like a fan. The fans I have are 24 VDC 0.2 amp, brushless.

Also, I need to activate a refrigerator motor, which is 120 VAC 1.1 amps. I've been trying to research this myself, but there seem to be many different devices that might work. Should I be worried about noise from these motors contaminating the digital side of the system? I'd really appreciate any help.

Dan Green, Jr.
Lynnwood, WA

A. The best solution is a solid-state relay — SSR. The driver output from the microcontroller/PC can be either high or low, because the SSR uses an LED interface. That is, your processor output and the load are forever isolated and you decide which logic turns on the relay. To illustrate, realize that the "coil" of a solid-state relay is nothing more than an LED. Given that premise, you can make the outputs of whatever TTL-compatible interface work with the relays in Figure 3. If you want the relay to be on, with the output low, the IN+ terminal has to be connected to +5 V. If you want the relay to be on when the logic output is high, then the IN- terminal has to be grounded. A suitable SSR for your AC-powered refrigerator is the Sharp S101N12, available from Digi-Key (800-344-4539; **www.digikey.com**).

Although there are DC-voltage solid-state relays, they can get expensive. With your meager voltage/current requirements, I'd build the SSR from scratch, using a 4N25 chip and a transistor, as shown in Figure 4, and save a lot of dough.

Again, the relay can be logic high or low activated — you decide. What I've done here is interface the 4N25 to the microcontroller/PC output and boost its current level to 800 mA, using a 2N2222A transistor. I've shown the controlled device as a fan motor, but you can control any DC-operated device within the 2N2222A's 40 volt, 800 mA power range.

Commodore Still Alive

Q. I am trying to replace a defective Commodore Plus/4 power supply, but I'm not having much luck. A friend gave me the schematic (Figure 4), but some of the values are missing. I wonder if you know what they are.

Craig Cook
Oak Harbor, OH

Solid-State Relay 40V, 800mA

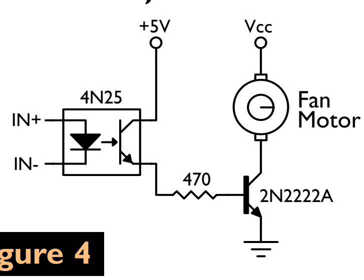


Figure 4

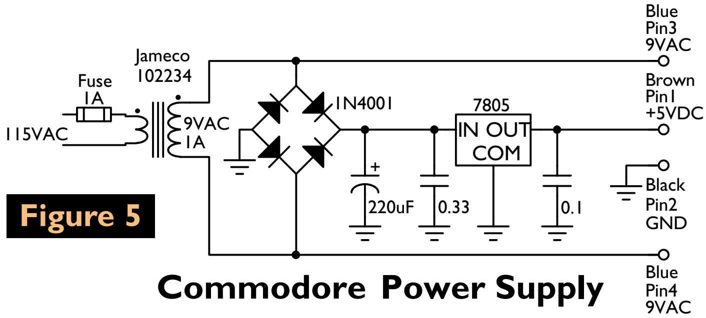
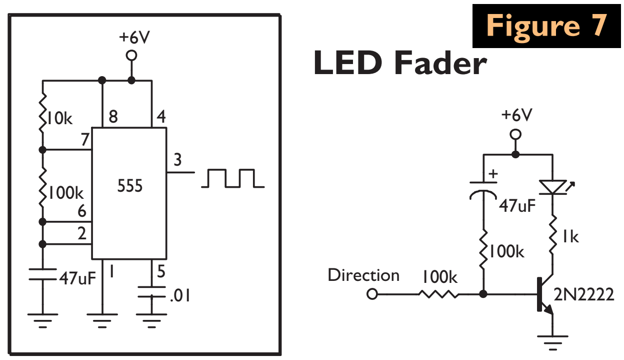


Figure 5

Commodore Power Supply

Figure 7

LED Fader



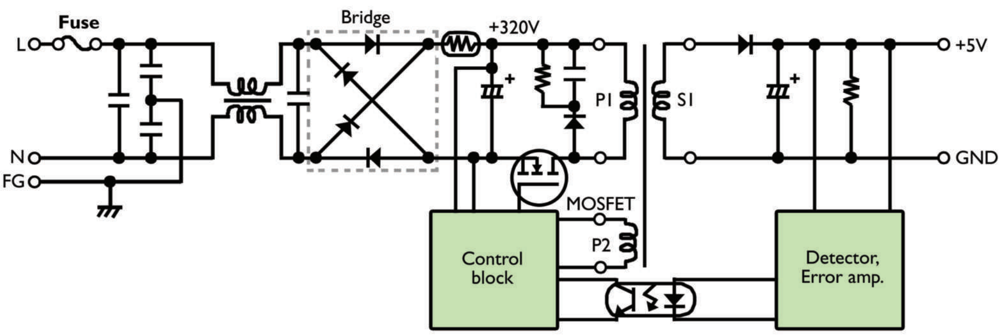


Figure 6

Off-Line Switching Power Supply

A. The power supply for the Plus/4 is the same as the C-64 — a black brick with two output voltages: 5 volts DC at about 1 amp and 9 volts AC. With a plug change, you can use the C-64 power supply with the Plus/4, but I would recommend a more reliable power pack than the old Commodore brick, like the one shown in Figure 5.

The transformer is a 9 VAC wall-wart that you can buy from Jameco (800-831-4242; **www.jameco.com**) for about $5.00. The design calls for four 1N4001 diodes, but feel free to substitute a full-wave rectifier, like the DF04 (Jameco 102971). Be sure that you heatsink the 7805 regulator to prevent thermal shutdown.

Off-Line Power Supply Basics

Q. I have a Citizen GSX-130 DMP printer that has a power supply problem. There is high voltage DC present, but no 5 or 27 volt output. It looks like an SMPS type of circuit because the transformer has a primary and a secondary winding, plus a large power transistor. Markings on the transistor are K1452 and 1E3. Where can I find a schematic diagram and information on the power transistor?

John Brittan
Schoolcraft, MI

A. I can't find a specific schematic for this printer, but a generic version of what you describe is shown in Figure 6. The transistor is a 2SK1452 MOSFET with a reverse breakdown voltage of 450 volts and a maximum forward current of 10 amps. A suitable substitute is the NTE2394.

The fact that you have high voltage leads me to believe the problem isn't the transistor itself, but the control circuitry that drives the transistor. The controller can be anything from a simple comparator (like an LM339) to a dedicated IC controller.

Moody LEDs

Q. I create artwork with LEDs and I need a simple, cost-effective method to slowly fade an LED from bright to dim, then to bright again over a period of about two seconds — like the sleep indicator on my MAC Titanium. Could you supply such a circuit diagram, preferably one that does not require an IC?

Chris Raney-Phairoh
via Internet

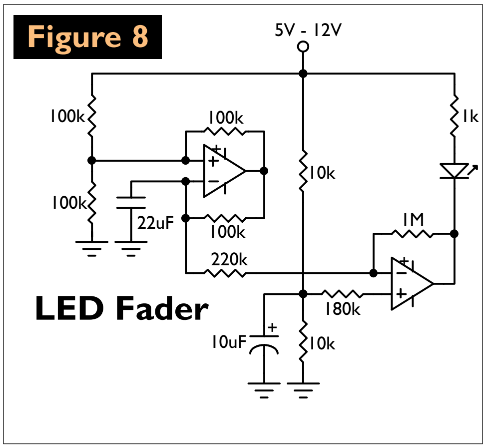


Figure 8
LED Fader

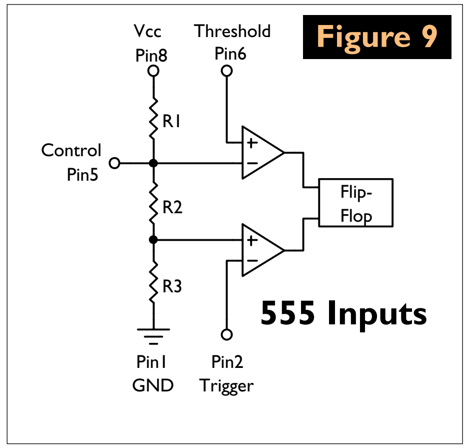


Figure 9
555 Inputs

A. The answer is a qualified yes. Yes, I can provide a fader circuit using transistors, but it requires three transistors, or more, plus a handful of resistors and capacitors. However, you might want to try the circuit in Figure 7. It's compact, cheap, and easily tucked into a small space. The problem is that the Direction pin has to be toggled between Vcc and GND to create the cycling effect. This signal can be supplied by a square-wave generator, like the 555 oscillator shown in the insert box, which can be located far away from the LED itself (notice that a third wire is required) and can be used to drive more than one LED fader. Unfortunately, the Direction signal has to be synchronized with the time constant of the RC combination to be fully effective. Otherwise, you get one with a lot of on/off time lag (which may be beneficial in some situations).

A better solution is to generate a triangular wave and use it to drive the LED, like the circuit in Figure 8. While this looks complex, the part count is less than a transistorized equivalent and the fade time is controlled by a single component: the 22 µF capacitor. More capacitance means slower fade time. Any op amp will work, but using a dual op amp combination, like the LM358 or equivalent, will considerably reduce the size of the module.

The Mysterious 555 Control Input

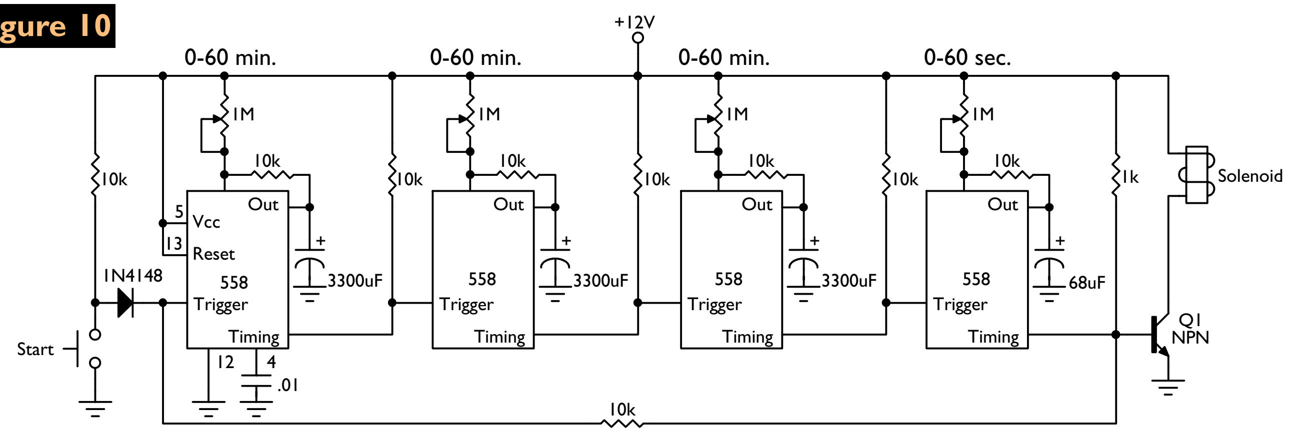
Q. In your designs, you place a .01 capacitor on pin 5 of the 555. I notice that, in other designs, it is sometimes there and sometimes it is not. In my experiments, it seems that this serves no noticeable purpose. Would you mind providing a short explanation as to why it is there?

Calvin Hirmke
Denver, CO

A. Inside the 555 chip is a resistance voltage divider that steers the operation of the comparators and flip-flop (Figure 9). Pin 5 (Control) allows direct access to the upper comparator. By applying a voltage to this pin, it's possible to vary the timing of the device independently of the RC network. For example, the control voltage may be varied from 45% to 90% of the Vcc in the monostable mode, making it possible to control the width of the output pulse. When it's used in the astable mode, the control voltage can be varied from 1.7 V to the full Vcc to produce a frequency-modulated (FM) output.

When the Control pin is not used, it's recommended that it be bypassed to ground with a small, ceramic capacitor of about 0.01 µF for immunity to noise to the comparator input and to prevent false triggering. This is particularly critical when using the CMOS version of the 555.

Figure 10



558 Timer

Prevent Compressor Rust

Q. I am trying to build a timing circuit to operate a drain valve for my air compressor. Basically, I need two timers, both independently adjustable by using potentiometers. The first timer needs to be adjustable from 30 to 180 minutes; the second timer needs to be adjustable from 15 to 60 seconds. When the time is up on the first timer, it starts the second timer. This opens a solenoid valve to drain water from the compressor's air tank. This cycle repeats itself over and over to guarantee that there is no water build up in the storage tank.

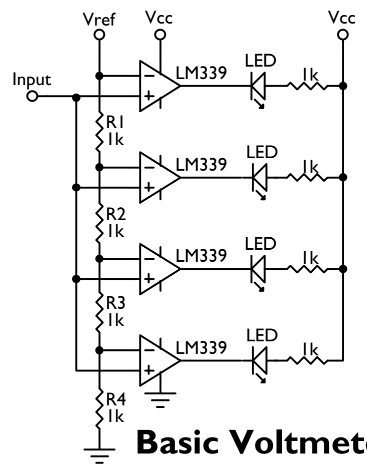
Bill Blackburn
via Internet

A. This design cries for an NE558 timer IC — a specialized version of the 555, with four timers in one

package. Unlike the 555, the timer stages of the 558 can be cascaded without the need for coupling capacitors, thus making the design simpler. In fact, it lends itself well to ring-counter topology, which is the design I'm using for your circuit (Figure 10).

The timers are arranged in a ring, with the output of the last timer looping back and triggering the first timer. The sequence is initiated when you press the "Start" button. When the first timer times out, it triggers the second, which sequentially triggers the third. The first three timers — which represent your first timer state — are calibrated for 0 to 60 minutes delay using the 1 M potentiometer. Their total time is the sum of the three dials. For example, if each pot is set for 30 minutes (half rotation), the total time is 90 minutes.

The final timer (0-60 seconds) actuates the water valve. For this part of the design, you're on your own. You need to select a transistor (Q1) that can carry the current the solenoid requires and provide any EMF protection (via a diode or MOV). The transistor must also have enough gain to be fully saturated when the output of the final 558 timer goes high. Because the 558 has an open-transistor output, the value of the pull-



Basic Voltmeter

Figure 11

Audible Continuity Tester

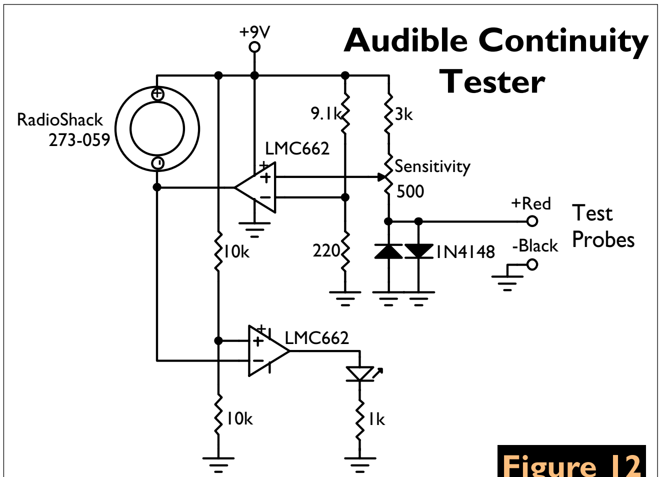
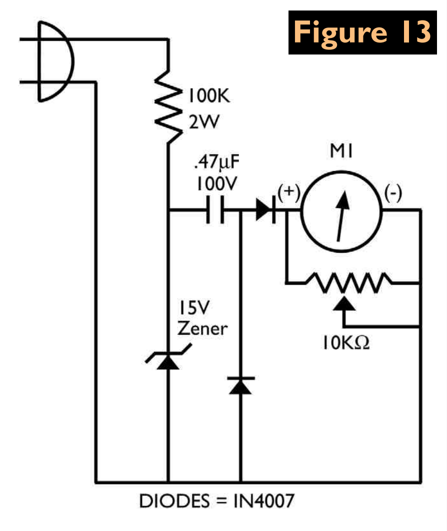


Figure 12



down resistor (1 k) can be as low as 120 ohms before the 558's ratings are exceeded, which should be plenty of base current to saturate a 5-amp transistor, like the TIP120. When the valve closes, the first timer is triggered again and the loop continues.

My Bucket Has a Hole in it

Q. I need two Seticon SAD4096 (Bucket Brigade) ICs — the ones used in a Centaur (1980s) pinball game. Are equivalent ICs useable as replacements or is there an alternative design arrangement available to perform the same function? Some functional limitations might be acceptable if they are known.

C. Casiday
cccas@dslextreme.com

A. Once the mainstay of solid-state audio delay, Bucket Brigade ICs are long obsolete. Today, the signal is digitized and stored in memory (typically RAM) for retrieval at a later time, much like the way digital oscilloscopes create signal delay. The maximum delay time is determined by the digitizing rate and the depth of the memory. I'm afraid this would be more of a project than you want to undertake for your "toy".

Fortunately, there are still a few Bucket Brigade chips floating around out there. They can be found in old musical reverb units (including some kits) from the 80s and electronic organ boards of the same era. You aren't limited to the Seticon SAD series. Chips from Panasonic (the MN30xx/MN32xx) and Reticon (R5106) can be made to work using a daughterboard that plugs into your existing sockets. Try the following two websites first. If they don't work, let's hope one of our readers will have a few laying around that they are willing to part with. Good luck!

www.parastream.com/hardware
www.analogman.com/parts.htm

Oops — Corrections Ahead!

It appears that errors appeared in two schematics published in the January 2004 issue. Here are the correct drawings.

Figure 11 (Figure 1 in the Jan. issue), the "LED Voltmeter," has the wrong comparator designation — it was originally designed for an LM324. Here is the correct schematic for the LM339 comparator. Figure 12, the "Audible Continuity Tester," has an extra line that looks like a wire and creates a short on the input probes. Here is the correct schematic.

MAILBAG

Dear TJ,

In regard to your answer, "High-Power PM Speed Controller," that's a sizable motor with a pretty "stiff" input characteristic. Your circuit would be just fine with a series-wound motor, but Paul should expect to see peak currents of 100 amps or more until the motor comes up to speed.

Limiting these peak currents could be achieved by something as simple as using a long (20', say) piece of line cord, like the one on a vacuum cleaner, because of its significant resistance. I use this technique for powering up things that can be dead shorts because you have enough time to figure them out and pull the plug before the breaker or fuse pops. This motor is similar to one I took off a treadmill and I noted that it used an inductor (about the size of a small avocado) with the speed control, doubtless to limit current.

If Paul goes ahead without a long cord or an inductor, maybe the solid-state stuff should be sized to handle about 50 amps RMS. He may be better off dialing the speed up, not just plugging it in with the high speed already set. By the way, these speed controllers are for sale from places like Johnstone Supply and WW Grainger.

Rosser B. Melton, Jr.
Denton, TX

Dear TJ,

Here is a schematic for a very simple 60 Hz frequency meter (Figure 13) that I use in my motor home. It uses less parts than the one you published in the January 2004 issue ("RPM to Hertz") and is probably just as accurate. As I remember it, the meter is a 1 mA movement, scaled 0 to 10, with six being the 60 Hz point that I calibrate from the commercial power line.

Rick Shepard AI5H
via Internet

Cool Websites!

Mars Rover JPL website. Updated daily.
http://marsrovers.jpl.nasa.gov/home/index.html

MarsDaily: Your portal to Mars
www.marsdaily.com/

Space telescopes:
Chandra X-Ray Observatory
http://chandra.harvard.edu/

GLAST
http://glast.gsfc.nasa.gov/public/resources/brochures/trifold/trifold_web.pdf

Hubble
http://hubblesite.org/

Spitzer (Space Infrared Telescope Facility)
www.spitzer.caltech.edu/

XMM-Newton
http://sci.esa.int/sciencee/www/area/index.cfm?fareaid=23

A HIGH-DENSITY 1U 350 WATT POWER SUPPLY FOR DISTRIBUTED ARCHITECTURE APPLICATIONS

Emerson Network Power, a division of Emerson, has introduced a new 350 watt bulk power supply in a compact package that is ideally suited for product designs using distributed power architecture. The high-efficiency switching power supply from their Astec Power division is the first model in the new high-density 4 x 7 power supply family. The NTS353 weighs in at 8.3 watts per cubic inch and can deliver up to 350 watts of total power.

Featuring active power factor correction to minimize input harmonic distortion, the Astec Power NTS353 is a compact 85-264 VAC power supply that is ideal for 1U (1.75-inch) rack installations and other low-profile applications. The unit can deliver its full rated output of 350 watts with 30 CFM forced air or 200 watts with convection cooling.

The device is also suited for use as an AC-DC front end for DC-DC converters in a wide variety of applications, including telecommunications, networking, test and measurement, single-board computers, and gigabit Ethernet devices. A built-in ORing diode eliminates the need for external circuitry when using the unit in a redundant configuration. For maximum versatility, it is also available with a top cover fan, designated by a –CF suffix on the model number.

Only 1.5 inches high, the Astec Power NTS350 has a footprint of only four by seven inches and can be set up for lengthwise or crosswise airflow, giving designers layout flexibility.

The device also features a 12 V 1 A auxiliary output and 5 V at 2 A standby output, as well as overload, overvoltage, and thermal protection.

The Astec Power NTS353 includes a built-in Class B EMI filter, remote sense, remote inhibit, and single-wire parallel on the primary output that enables current-sharing to balance loads. It also has an operating temperature range of zero to 50°C without derating and can function up to 70°C by derating the output 2.5 percent per degree Celsius. It complies with IEC EN61000-3-2 harmonic and IEC EN61000-4-X susceptibility standards.

With a demonstrated mean time between failures (MTBF) of over 550,000 hours at full load in 25°C ambient conditions, as well as excellent vibration tolerance, the units are designed for long life and trouble-free operation. They also comply with worldwide safety and performance standards from UL, CSA, VDE, NEMKO, AUSTEL, CB, and CE.

Available now, pricing begins at $299.00 in OEM quantities. For more information, please contact an Astec Power representative in your area. To locate a representative, go to the Astec Power website and click on the sales office button on the home page.

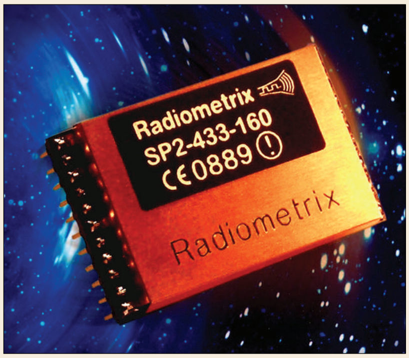
For more information, contact:

ASTEC POWER
5810 Van Allen Way
Carlsbad, CA 92008
Tel: **760-930-4600**
Email: **tomtillman@astec.com**
Web: **www.astecpower.com**

Circle #117 on the Reader Service Card.

WIRELESS INTERFACE MODULE AND EVALUATION KIT

LEMOS International has announced the SPM2-433-28 Transceiver bi-directional wireless interface module, available in 433.92, 869.85, and 914.5 MHz frequencies. Complete with built-in command line configuration and link diagnostics, the SPM2-433-28 even has remote open-air unit configuration capability; it has a range up to 200 m outdoors and 50 m indoors. The SMP2 has a DTE speed of 600-115,200 bps and an air data speed of 600-14,400 bps. It has point-to-point addressability and provides point-to-multi-point and broadcast capabilities. With a digital serial interface and hardware-free flow control, the unit also has a low operating current and auto standby mode. An evaluation kit is available for the 23 mm x 39 mm x 4 mm SPM2-433-28, which conforms to EN300 220-3 and EN301 489-3.



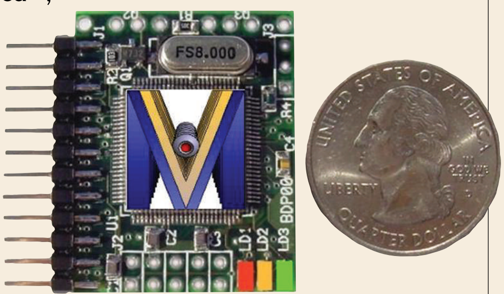
The SPM2 Evaluation Kit is compatible with PDAs, organizers, and laptops; it is suited for all handheld and portable terminals, as well as EPOS equipment, barcode scanners, and belt clip printers. It is ideal for many data acquisition and monitoring applications, including audience response, in-building environment, advanced security and fire alarm, restaurant ordering, and vehicle data systems.

For more information, contact:

LEMOS INTERNATIONAL CO., INC.
1305 Post Rd., Ste. 305
Fairfield, CT 06430
866-345-3667 Fax: **203-254-7442**
Email: **sales@lemosint.com**
Web: **www.lemosint.com**

Circle #140 on the Reader Service Card.

TINIPOD™ — TINY CONTROLLER IS POWERFULLY FEATURED



The new TiniPod™, a tiny 1.0" x 1.3" controller board, ships this month from New Micros, Inc. The TiniPod is a complete micro-controller system with a built in high-level-language and parallel processing operating system, IsoMax™.

Hardware features on this new processor include 16 General Purpose Digital I/O lines, one RS-232 serial channel, and CAN Bus. The GPIO lines share functions with a four-wire SPI Interface, six General Purpose Timers, and six Pulse Width Modulation (PWM) outputs.

The PWM outputs are hardware based and can be used to control six R/C Servos or grouped to control three-phase Brushless DC motors, six PMDC motors, or as complementary H-bridge drivers for three PMDC motors.

The multimode Timers can be used as three channels of Quadrature Decoders or three channels of Step and Direction counters. Individually, they can also measure pulse width, time ultrasonic ranging pulses, generate pulses, or drive IR 40 KHz transmitters, etc. They can also generate PWM outputs to drive another six R/C Servos.

Since the PWM and Timer modules are supported in set-and-forget hardware modules, the processor is free to perform higher level functions, such as acceleration-limited, velocity-profiled control of the moves of up to 12 R/C Servos at the same time, and still have time left over for other tasks.

Similarly, using the Timer modules as Quadrature decoder inputs, the processor can implement PID and acceleration-limited, velocity-profiled control of the moves of three axes of motion control at the same time, and do other tasks such as communications via serial or CANBus.

The CANBus opens the possibility of distributed processing networks, particularly in automotive and industrial applications, so parallel hardware can be combined with parallel software. The TiniPod can be programmed in a number of languages: C (third party), Small C (included), Forth, or the resident IsoMax (included).

IsoMax is based on state machine programming concepts. Programming real time tasks amounts to describing virtual machines that will sense conditions, take actions, and move to new states. The machine construction is very readable. Development is interactive through the RS-232 and will typically be done on a PC, laptop, PDA, or any serial device — even dynamically by another microprocessor. Programming in IsoMax means interactively creating new processor tasks — each being a state machine or thread — and then testing that code.

Virtually Parallel Machine Architecture (VPMA) is a new programming paradigm possible with IsoMax. VPMA allows more than one of these machines to be installed into the background process. All these installed machines run independently in a virtually parallel fashion. All the tasks are handled on the same level, with each running like its own separate little machine. VPMA on the TiniPod can be compared to running dozens of Stamp-like microcomputers in parallel.

When the programmer is satisfied with performance of a new machine, it can be installed into a chain of machines. The machines installed in the chain become background features of the TiniPod until removed or replaced.

The IsoMax language is inherently "multitasking" without the overhead or complexity of a multitasking operating system. A useful single state machine can be written with as little as three lines of code. The interactive foreground always remains available for further interactive development and interactive checking on the running machines. The combination of IsoMax software, VPMA structure, and diverse hardware makes TiniPod very versatile. TiniPod is ideal for dedicated control of DC motors, BDCM, stepper motors, solenoids, and motion and control applications in general. It also works well for data collection and many networked control applications.

The TiniPod was made incredibly small, while still maintaining large enough connectors for easy human access. All connectors have .1" spacing. The board is only 1.0" x 1.3" and plugs into a prototype area or socket just 0.2" x 1.2".

The TiniPod brings an amazing amount of computing and control function to a very small space at a very reasonable cost. A single unit is $79.00 with linear regulators installed. Other regulator options are available.

For more information, contact:

NEW MICROS, INC.
1601 Chalk Hill Rd.
Dallas, TX 75212
Tel: **214-339-2204**
Email: **nmisales@newmicros.com**
Web: **www.newmicros.com**

Circle #133 on the Reader Service Card.

PDV-040 POCKET DIGITAL VIDEO RECORDER

EverSecure™, a Matco Company, introduces the new PDV-040 Pocket Digital Video Recorder, specifically designed for mobile surveillance applications.

The PDV-040 can record any audio/video resources and covert them in real-time into near DVD quality MP4 video and store them into its built-in 20GB HDD, for a maximum of 42 hours of MP4 video recording (40GB HDD).

It can also be applied as an audio recorder via its built-in microphone, storing data on its hard disk in MP3 format. Audio data can be archived to PC via its built-in USB 2.0 interface.

Substantially smaller than previous DVR devices, the PDV-040 is powered by either a rechargeable Lithium-ion battery or 12 VDC. The unit comes standard with composite A/V input/output ports. Display is available on its built-in 3.5" TFT LCD color monitor or a connected TV or projector. The package also includes earphone, carrying case, battery charger, and cables.

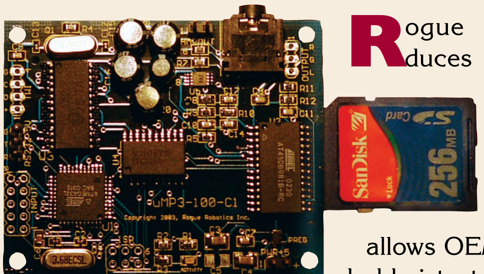
Overall dimensions are 5-1/8" W x 3-3/8"H x 1-3/8"D. Total weight is 0.67 lbs.

For more information, contact:

MATCO, INC.
2246 N. Palmer Dr., Ste. 103
Schaumburg, IL 60173
Tel: **847-303-9700; 800-719-9605**
Fax: **847-303-0660**
Web: **www.matco.com**

Circle #123 on the Reader Service Card.

MAKE NOISE WITH THE SERIAL µMP3 MODULE



Rogue Robotics introduces the new µMP3™ (pronounced "micro MP3") serial MP3 module. The µMP3 module allows OEM designers and hobbyists to integrate high quality MP3 playback into projects using an easy-to-use TTL serial control protocol.

The µMP3 module also has a multi-function, eight-pin connector that operates in either direct sound playback (eight configured files or playlists) or push button player mode (play, stop, forward, etc). Each module has a stereo headphone jack and a mono 325 mW amplified speaker connector.

The module has 1 MByte of onboard flash storage and a connector on the reverse side for an SD/MMC card up to 1 GB in size in FAT16/32 format. MP3 Playback is CBR or VBR and up to 48 KHz at 320 Kbps.

The µMP3 module is a small (2.5” by 2”) footprint board. The TTL serial is configurable from 9600 to 115 K bps. It requires a 5 V-regulated source at 150 mA and has an onboard 3.3 V LDO regulator.

Software for MP3 organization, I/O configuration, and play list creation is included. The kit also includes a bundled text to MP3 speech creation package — Text Aloud MP3 — trial version (30 days from Nextup.com).

The µMP3 module is perfect for OEM, kiosk, advertising, real estate, robotics, or any project where you want to make your product produce clear speech or music. With up to 4,000 files per device, you can create libraries of speech or music, controlled from your microcontroller.

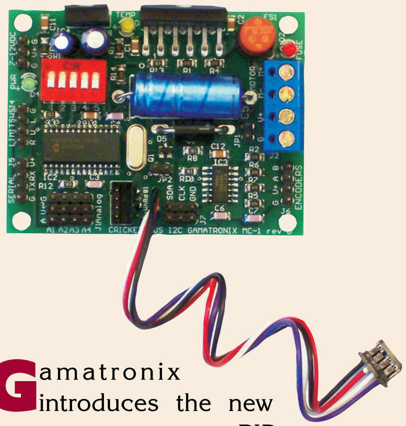
The µMP3 module retails for $99.95 (US, qty. one) and only $49.00 each (US, qty. 1,000).

For more information, contact:

ROGUE ROBOTICS
103 Sarah Ashbridge Ave.
Toronto, ON M4L 3Y1
Canada
Tel: **416-707-3745** Fax: **647-439-1577**
Email: **info@roguerobotics.com**
Web: **www.roguerobotics.com**

Circle #108 on the Reader Service Card.

THE SMART MOTOR CONTROLLER



Gamatronix introduces the new Gamoto, a smart PID closed-loop motor controller designed with robot hobbyists and students in mind. Key features include power, precision, speed, communication options, and ease of use.

Gamoto is smart — it gives you three choices for communication: I2C bus, a Cricket Bus connector with pigtail for easy plug-in to the Handy Cricket system, and a serial port connector for serial control at 9,600 or 19,200 baud. A native OOPIC Gamoto Object is in development.

Gamoto is flexible — up to eight Gamotos can be on the same I2C or Cricket bus. The address of each motor is set using dip switches.

Gamoto is strong — high-speed encoder feedback allows precise control over position, speed, and acceleration of brushed DC motors up to three amps. Trapezoidal motion profile processing allows acceleration ramp, constant velocity cruise, and then deceleration ramp down. Eight profiles can be stored in flash.

Gamoto is sensitive — current sense feedback actively detects torque and collisions. Four analog inputs allow connection of additional sensors.

And, lastly, it’s easy going — the firmware is upgradeable.

For more information, contact:

GAMATRONIX
Tel: **978-567-8925**
Email: **sales@gamatronix.com**
Web: **www.gamatronix.com**

Circle #151 on the Reader Service Card.

by Martin Dubuc

Adding Sound To Your Projects

Grab Ears Along With Imaginations

This Month's Projects

The Fuzzball Rating System

To find out the level of difficulty for each of these projects, turn to Fuzzball for the answers.

The scale is from 1-4, with four Fuzzballs being the more difficult or advanced projects. Just look for the Fuzzballs in the opening header.

You'll also find information included in each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!

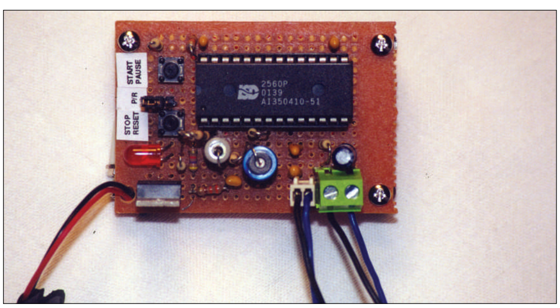
Winbond offers a suite of integrated circuits that you can leverage to add sound capability to your electronic projects. I will introduce two of their product lines — the ChipCorder and the Text-to-Speech integrated circuits — and discuss some of their applications. Winbond voice and speech chips use a similar architecture. These chips contain four major blocks: non-volatile memory (also called NVRAM) to store uncompressed voice or audio, the necessary functions to process audio input, the required circuitry to produce audio output, and the digital logic that controls the behavior of the chip. Data stored in non-volatile memory is persistent, even when power is removed from the circuit.

ChipCorder

The ChipCorder product line implements voice record and playback capabilities. Several messages can be stored on the ChipCorder integrated circuits. They can then be played back on demand. This product line is broken down in several families. We will look at the ISD25xx, ISD400x, and ISD5x16 families. Each chip offers unique recording duration, sound quality, audio features, and control mechanisms.

ISD25xx

The ISD25xx can record between 60 to 120 seconds of sound, depending on the model. All models have the same amount of memory (480 K cells, segmented in 600 rows). The recording length varies according to the sampling rate used by each model. A device that records longer uses a lower sampling rate (lower recording quality). For 60-second recordings (ISD2560), the sampling rate is 8 kHz. For 120-second recordings (ISD25120), it is 4 kHz. The sampling rate defines the quality of the recording. To give you a basis for comparison, compact disks are sampled at 44.1 kHz, while voice on your telephone is sampled at 8 kHz. The ISD25xx contains the circuitry to receive three different types of audio inputs: microphone (MIC), audio in (ANA IN), and auxiliary in (AUX IN). The ISD25xx also contains the amplification circuit for the audio output. A speaker can be attached directly to the chip without an external amplification stage. ISD25xx can be cascaded together for longer duration.

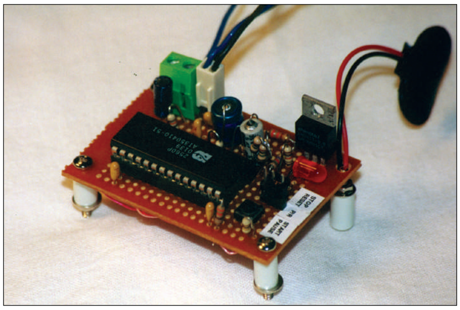


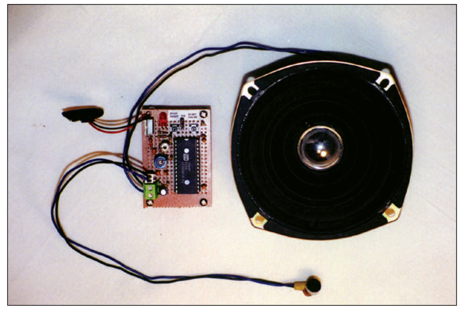
The operation of the chip is straightforward. The P/R pin is used to indicate whether the chip should be recording (low) or playing back (high). The chip enable pin is used to start or stop the record/playback operation. When the chip enable pin is low, the chip starts the record or playback operation at the address specified by the address input pins (A0 to A9). In playback mode, the chip outputs the audio until it reaches the end of message (EOM) marker. When the EOM marker is encountered, a pulse is applied on the EOM pin. In record mode, when the end of memory is reached, the OVF output pin goes low. The interface of this device to a microcontroller requires 15 pins (five for control and 10 for address selection). The ISD25xx offers a mode where messages can be recorded and played back sequentially without the need to specify addresses explicitly, translating into significant savings in the interfacing pin count. If address input pins A8 and A9 are set high, the chip can be configured to work in one or more of the six operational modes. One of these operational modes is the push-button control operational mode. When this mode is selected, the chip can record a series of messages strictly using the chip enable (CE) pin (Start/Pause function), the program/record (P/R) pin, and the power down (PD) pin. The ISD25xx, running in push-button control operational mode, is a very straightforward way to implement voice record/playback functionality. The P/R pin indicates whether the chip is in record

or play mode. The CE pin is used to start and pause the recording or playing. The third pin, PD, is used to reset the chip. There is no need to specify the address in this mode. The chip always performs the requested operation starting at the current address. After reset, the chip points to address zero. Other operational modes can be used to alter the behavior of the chip. For instance, the chip can be told to only report the EOM marker when the chip finishes playing the last message, instead of at the end of each message. When the looping mode is active, the chip jumps back to address 0 when it reaches the end of recorded messages, allowing the recording to loop. The ISD25xx comes in various packages: 28-pin SOIC/PDIP and 32-pin TSOP.

ISD4003 and ISD4004

The ISD4004 family offers similar voice record/playback functionality to the ISD25xx family. However, as opposed to chips of the ISD25xx family, it can be controlled with a more sophisticated interface and offers a considerably larger memory size. The ISD4003 can store up to 1,920 K cells to provide four to eight minutes of recorded voice/audio. Like the ISD25xx, as the recording length increases, the sampling rate decreases. The ISD4003-04M features four minutes of 8 kHz sampled audio/voice. The ISD4003-08M model features eight minutes of 4 kHz sampled audio/voice. Control of the chip is done using an SPI interface using the MOSI, MISO, and SCLK pins. Commands are sent on this interface to power up, play, record, perform message cueing, stop current operation, and read the interrupt status bits. Overall, the ISD4003 does not provide more control options than the ISD25xx, but the full range of capabilities can be exercised through the SPI, which may greatly simplify circuit and firmware design for some types of applications. ISD4003 chips do not have a speaker output. External output amplifier circuits must be connected to the AUD OUT pin to drive a speaker. The ISD4004 family is identical to the ISD4003 family, except for the size of its NVRAM. The NVRAM contains 3,840K





cells and provides eight to 16 minutes of voice recording at 4/8 kHz sampling. The ISD4003 and ISD4004 families also come in various packages: 28-pin SOIC, PDIP, and TSOP.

ISD5116 and ISD5216

The ISD5116 and the ISD5216 families are the most advanced of the ChipCorder chips presented in this article. They implement voice record/playback capabilities similar to other ChipCorder chips, but offer a richer feature set. The memory size of the ISD5116/ISD5216 is the same as the ISD4004 (segmented in 2,048 rows). However, the sampling rate of these models can be programmed through software. If a 4 kHz sampling rate is selected, the chip can record up to 16 minutes of speech. If 8 kHz sampling is selected, the chip can record up to eight minutes of speech. The ISD5116 and ISD5216 also have the ability to store digital data. This is typically used to store system configuration and other application data, such as phone numbers. The data can be stored as 2,048 rows of 2,048 bytes. The ISD5116 uses an I2 C two-wire interface for control purposes. This interface is used to control the operation of the chip (play, record, perform message cueing, and stop), but is also used to configure the chip and provide operations to store and retrieve digital data. The ISD5116 and ISD5216, like the ISD25xx, contain a speaker driver. They also offer an AUX OUT output. Unlike other chips in the ChipCorder family, ISD5116 and ISD5216 chips implement adjustable volume control and amplification gain. These chips also provide a feed through mode (voice captured by a microphone can be configured to go directly to ANA OUT). Voice can be recorded on two simultaneous channels (microphone and ANA IN), which enables the recording of both sides (duplex) of a conversation. The above characteristics make these chips good choices for more complex applications, especially those targeted at cellular phones or other portable devices. In addition to the features of the ISD5116, the ISD5216 contains an integrated CODEC to record and play back digital audio (PCM, Law, etc.), a capability that is especially useful in telephony applications. The ISD5116 and ISD5216 families come in the following packages: 28-pin SOIC, PDIP, and TSOP.

Text-to-Speech Integrated Circuits

Winbond also manufactures the WTS701 text-to-speech integrated circuit. The WTS701 chip can produce English or Chinese/Mandarin speech from commands it receives on the SPI port. The commands contain the text to synthesize in ASCII format. The chip normalizes the ASCII text, converts words into a sequence of

phonemes, and sends the appropriate audio stream to the digital or analog output circuitry. The normalization process consists of expanding abbreviations and numbers into pronounceable words. The audio streams for the phonemes are built into the chip's memory. The chip also contains a dictionary that converts words into sequences of phonemes. The chip provides commands to download different language, speaker, and normalization databases. The WTS701 contains the same CODEC as the ISD5216, which makes it possible to output the speech in digital form.

The WTS701 has a built-in speaker driver and an AUX OUT output. The WTS701 chip is only available in 56-lead TSOP, which makes it difficult to include in homegrown prototype boards. However, for hobbyists, Devantech manufactures the SP03 Text-to-Speech Synthesizer module which is based on the WTS701 integrated circuit. These modules come with a piezo speaker. Up to 30 phrases can be stored on the module PIC microcontroller or text can be sent directly on one of the three supported interfaces: RS232, I2 C, and parallel. These modules can be purchased at **www.acroname.com** or **www.batz.com**

Applications

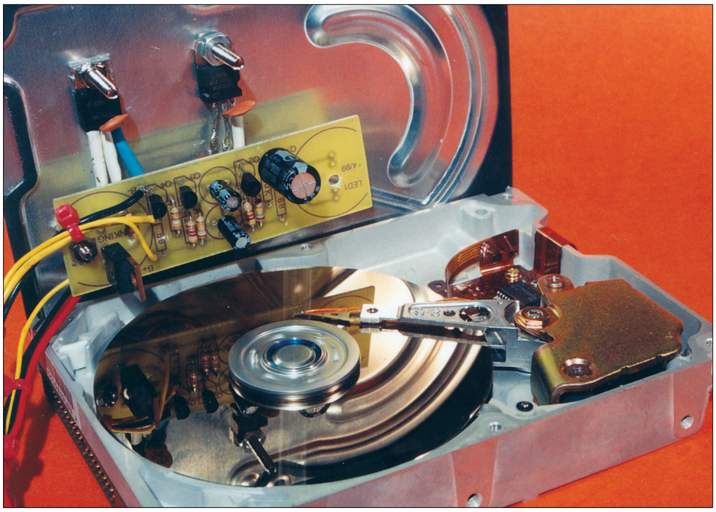
Winbond ChipCorder and Text-to-Speech integrated circuits open up a wide range of possibilities for audio applications. The voice and playback functions can be used to add sound to telephony products, toys, robots, and multimedia installations. The Winbond chips can be a very important part of many different messaging applications: automated response systems, voice mail, automotive communications, and GPS/navigation systems.

For telephony applications, the voice record and playback can also be used to record and play back DTMF tones. There is tremendous opportunity for cellular phone applications, including recording or downloading personalized ringers. Finally, the text-to-speech capabilities of the WTS701 can prove very useful for automated attendant applications. You can find the ChipCorder and text-to-speech integrated circuit data sheets and various application briefs on the Winbond website. These documents are well-written and contain several application circuits that show how to connect the chips to microcontrollers, input, and output devices. We have seen that Winbond provides a good selection of integrated circuits to handle voice messaging.

The ISD25xx family is well suited for the design of simple push-button driven circuits. In such designs, there is no need for a microcontroller to control the chip. For more sophisticated applications, the ISD5116 is a powerful chip that provides many features. Its I2 C interface simplifies its control. If the microcontroller used in the circuit does not support I2 C, then the ISD4004, with its SPI port, provides a suitable alternative. However, the ISD4004 requires external circuitry to drive speakers and does not contain some of the audio features of the other chips, such as automatic gain control. Finally, if there is a need to synthesize speech in your application, you can use the WTS701 Text-to-Speech integrated circuit. **NV**

A Simple HDD Exerciser

Breathe New Life Into That Old Hard Drive



My son, Tim, asked me, “Hey, Dad, can you make something like I saw at Comdex?" He had just come home from a computer-oriented seminar and wanted to find out if we could make the heads on a defective hard drive rattle back and forth for Show and Tell — silly question. His older sister, Joy, had asked about a louder metronome. His younger sister, Robbi, had asked about a violin-tuner. Joy now has a loud metronome and Robbi has a tuner (*Nuts & Volts*, November 1999). So, with that for an excuse, I shook my head up and down and headed for the workroom.

HDD

While the CPU (central processing unit) serves as the brains of a computer, the HDD (hard disk drive) stores the programs that the CPU processes. Some systems have more than one HDD. Some of the earliest computers stored the programs on a flexible (floppy) disk that the user inserted into a slot so the computer could access it. To change programs, change floppy disks. If you go much farther back in time than that, you would call your computer an abacus.

What's Inside

The more modern systems will have a hard drive that consists of two or more hard disks with magnetic pick-up heads on each side of the disks. The system is assembled in a clean room that is almost beyond imagination *(They really are - Editor Dan)*. Note the mirror-like finish of the disk in the photo. If a particle the thickness of a human hair gets into the assembly, it can trash the system. That is just one of the reasons why they have the labels warning that breaking the seal and taking off the cover will void the warranty — it would probably ruin the unit.

Extremely strong magnets drive the heads rapidly back and forth as the coil on the head assembly responds to current pulses sent to it. You do want to see your program on the screen sometime today, don't you? I can remember an early computer that took eight minutes to load the program. A later upgrade cut the time to two and a half minutes. I would expect that same program — if it came from a modern HDD — to load in a few seconds.

The strong magnets — probably some of the most powerful you are likely to run into — make this possible. The electronics on the bottom of the hard drive tell the head where to look on the disk and indicate when it has arrived there. This is a simplified version of what goes on, but explains some of the things that make an otherwise dead drive into an interesting and somewhat educational instrument.

Where to Get a Used Drive

I worked in an electronics group that serviced laboratory equipment and took care of the computers in a large department at a state university. When one of the computer people would say that a drive needed replacing because it could no longer reliably store and retrieve information or it had just plain crashed, I stood there with my hand out.

You could probably find some older, obsolete, or even dead units courtesy of friends or a service place. If at all possible, have them plug the unit in and see if it will go through the initialization process. If not, politely decline the offer unless you want the magnets from it. Those are worth having — or you could make the seemingly simple head rattler out of the unit.

You might try looking in a thrift store. Sometimes they have ancient machines that work, but fall short of

most modern needs. Although not generally practical for computing needs, the machine will probably boot, which would let you know that the hard drive works, giving you the main ingredient for our educational toy.

Even after they otherwise die and can no longer serve as a data storage media, the parts of the system that make them "init" will still work most of the time. Of the three or four units sitting on my bench now, only one would not initialize. It may wind up shaking its heads back and forth another day. Perhaps we can talk about that in a later issue.

Init

When you first apply power to the drive — 5 volts and 12 volts — the disks start spinning up, going for their rated speed of anything from 3,600 to 7,200 RPM. The faster speeds allow faster access to the data.

When the machine decides that the disks have reached operating speed, the heads move around. They have to find track zero, the reference track. In the process of doing this self-test, they put on quite a show.

The display that Tim saw at the show simply put alternating pulses into the coil in the head, which drives it back and forth. When I started playing with a drive, I applied the normal 5 and 12 volts to the drive. That caused it to go through the initialization process. Once the heads found the reference position, the disks kept on spinning and the heads just sat on track zero.

Show Time

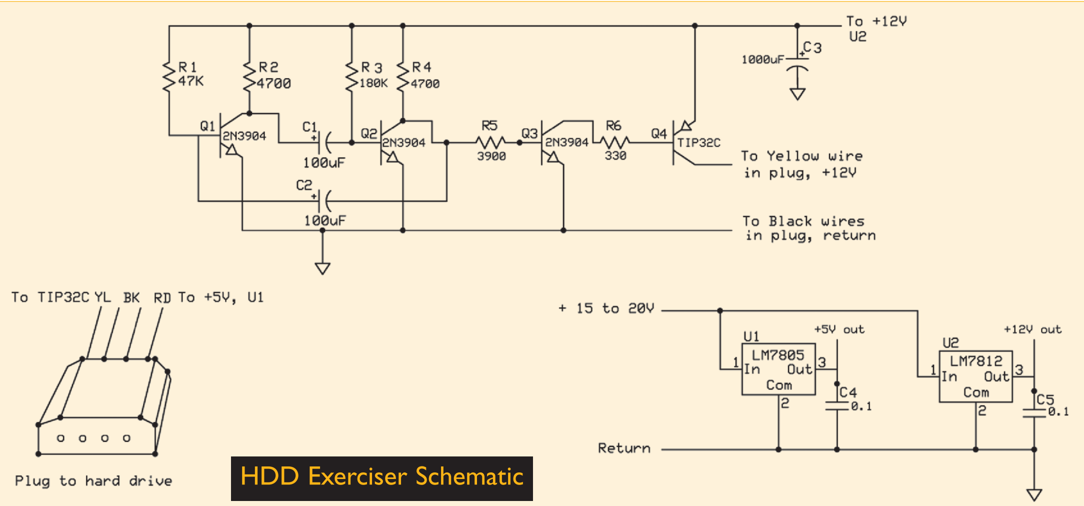
Interrupting the power for a second or so caused the show to restart. The heads would go to the center of the drive, while the disks spun up again. When they reached their speed, the heads moved to the middle of the active area, rattled back and forth for a few seconds — probably checking for mechanical defects — then went to the track zero position. That seemed like more fun than just watching the heads rattle from side to side.

Making it Automatic

You can make the drive put on this display by feeding it 5 volts and 12 volts at a total of about one amp. Then, periodically interrupt either power supply for anything from less than a second to maybe 10 seconds. The longer time allows the disks to spin most of the way down or even come to a complete stop. You can decide which one you like and adjust the values, as shown in the schematic.

What You Need

Of course, you will need one slightly used or obso-



HDD Exerciser Schematic

lete hard drive, a couple of three-terminal regulators, and either a slightly modified PC board or a home-built control board, as well as a nominal 15 volt, one amp power supply.

Circuit

A free-running multivibrator, sometimes known as a flip-flop, can give relatively repeatable timing pulses. You do not need precision pulses for this application. Feed the pulses, or more accurately, feed power to a transistor switch most of the time, interrupting it once in a while, for as long as you want, in order to get the desired effect.

In the schematic, Q4 serves as an easily interrupted power switch. When Q3 turns on, it connects the base bias resistor for Q4 to the minus battery lead. That turns on Q4 and applies the 12 volts to the drive. That starts the self-test Show and Tell cycle. This gives you an idea of what the heads do while seeking your data.

When Q1 and Q2 time out, Q2 turns on. This turns off Q3 and Q4 for a time determined mostly by the values of R1, R3 and C1, C2. Use the values shown if

you want the disks to spin down all the way in most drives. Some of them take just a few seconds and some of them take a good 10 seconds to stop. If you want the heads to move as much as possible, make C2 smaller so that it interrupts the power for just a short time.

Putting It Together

First, take apart the drive. This may require a common Phillips screwdriver, an Allen wrench, a Torx wrench, or all of them. Look for fasteners hidden under the warning labels. Once you get the screws out, the cover usually lifts off with the aid of a thin blade slipped under it. Set it and a couple of the screws aside. You can use them to hold the cover to the side, as shown in the photo.

Feel free to use a different means of supporting the board, even putting it in a small box along with the regulators. Keep in mind that the regulators do get warm and must be heatsinked. As you can see, I just put them on the old cover with screws long enough to hold the board. Then, I put the board on its own mounting stud: a 4-40 machine screw with three nuts on it. One holds the screw to the cover, the other two hold the board away from the cover.

Power comes in from the cable that is shown on the left side of the photo. Since the wall-mounted power module had a cable with a battery clip on it, a used battery clip taken from a dead 9 V battery made a convenient connector. This also makes it convenient to use the power module for other projects when the hard drive gets tired of exercising.

The Board

Once upon a time, I made a blinking light for Tim's bike. He wanted two large LEDs, blinking alternately and placed at the focal points of a trailer-type of side light. I wrote about that and other LED projects (*Nuts & Volts*, October 1999). Fred, from Far Circuits, made the final board, which you see in the photo. I changed a few of the values and added the output transistor, Q4. If you contact Fred for the board, ask for the bike light board from 8/14/99. I had one extra board left over when starting on this project. This saved a lot of time and gave it a nicer appearance.

The bike light board did almost everything needed here. Just leave off one of the original transistors, the LEDs, add a resistor, a power transistor, and wire it as in the schematic.

The power transistor approaches saturation, as it has only 50-75 mV, 0.05-0.075 volts across it when delivering the 12 volts to the drive. It never gets warm to the touch, so it does not need a heatsink — which is why it is mounted directly on the board. You will want the plug that fits the power socket on the disk drive.

Again, you can buy one or find one left over from a defunct power supply or inside a dead computer.

I suppose that you could still use one of the original LEDs for added effect, as it would show when the power to that part of the circuit turns on and off.

Parts List

R1	47K, 1/4 W
R2, R4	4.7K
R3	180K
R5	3.9K
R6	330Ω
C1	100 µF 16 V *(vary the value for effect)*
C2	100 µF 16 V
C3	1000 µF 16 V
C4, C5	0.1 µF 16 V
Q1-Q3	2N3904, 2N2222 small-signal, NPN transistor
Q4	TIP32 or similar plastic, PNP power transistor.

LM7812 three-terminal, 12 volt regulator
LM7805 three-terminal, 5 volt regulator
Perf board or PC board — or Bike Light from 8/14/99
FAR Circuits website catalog **www.farcircuits.net**
(847) 836-9148
15 to 20 volt, 1 amp unregulated DC power supply

Power Connections

The schematic shows the power connections. The red line goes to the 5 volt supply and the yellow line goes to the 12 volt supply. The black lines go to the minus — or the return — from the power supplies. Some of the drives show the voltages on the bottom of the control board. If they do, that will let you confirm your connections.

Winding It Up

After you mount the regulators, you may want to tie them to the connector and plug that into the drive to make sure that it does indeed play. When you finish playing, leave the 5 volt supply connected to the plug. Then, connect the output of the 12 volt regulator to the board and the output from Q4 to the yellow wire. You can check the operation of the driver board before plugging it back into the hard drive. You may want to tack in 2 to 10 microfarad capacitors for C1 and C2.

That could save a lot of waiting time. With the values shown, the output stage stays on or off for about 10 seconds. With 10 microfarad caps, the output stage should cycle about once per second. You can check that with a 12 volt pilot light in place of the drive across the yellow and the black wires. An analog meter would follow those changes. A digital meter would show changes. Any of those indications will tell you that the oscillator, Q1 and Q2, is turning Q3 and Q4 on and off.

Trouble?

If, for some reason, that does not check out, look for defective or incorrectly wired transistors or possibly a bad capacitor — C1, C2. Do include the two 0.1 microfarad caps across the output of the regulators or you could have some unpredictable events. Include C3 in that category once you connect this electronic switch to the hard drive, since many of the wall-mounted power modules have less than adequate filtering built into them. A lot of times, they depend upon the filters built into the equipment that they power.

Start Your Motor

When the power supplies (+5 and +12) and the switches check out, connect the plug to the hard drive, at which point you can send it to school for Show and Tell. Otherwise, you can just sit back, relax, and enjoy watching your hard drive while it exercises. (For my money, it beats watching daytime TV.) **NV**

A Simple One-MHz Frequency Counter

With an Introduction to Signal Conditioning

If you work with digital or analog oscillators, at some point you will want to double-check their operating frequency. Analog oscilloscopes will only get you within a half-order of magnitude or so; a good frequency counter will take you the rest of the way.

In this article, I will show you how to build a simple frequency counter, like the one shown schematically in Figures 1A and 1B. It has a response range from 1 Hz to 1 MHz, a resolution of 1 Hz, and a typical sensitivity of ±250 mV or less. The maximum input voltage is 30 VAC (using a 10X scope probe). This provides an accuracy of ±30 PPM at ±1Hz, with a supply voltage of 12 V @ 200 mA. The circuit is composed of an input amplifier, power supplies, reference clock, and eight-digit counter. I will explain the operation of each one in the following sections.

Input Amplifier

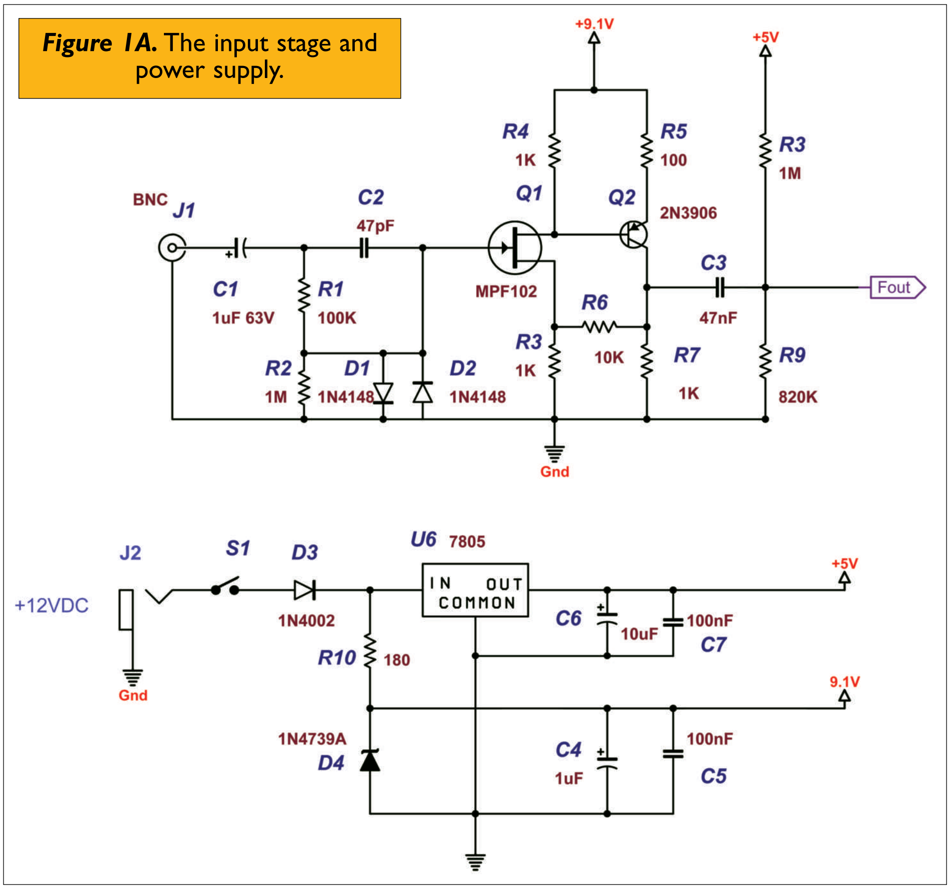
Examine Figure 1A, paying particular attention to the input stage. Diodes D1 and D2 clamp the input voltage of the FET to ±700 mV when high input voltages are applied. This stage is powered by 9.1 V to allow for maximum voltage swing at the collector of Q2 without clipping. This stage has a gain of between four and eight, depending on the input frequency. Note that, in order to work properly, the VGS (off) voltage of FET Q1 must be between -1.5 V and -3.5 V. The data sheet for the MPF102 specifies a maximum VGS (off) of -8 V. Typical values of VGS (off) are around -2 V.

In order to guarantee the proper operation of the amplifier, construct the test circuit given in Figure 2 to determine the VGS (off) of any given FET. Adjust R1 so that V-out is approximately 2 VDC. Turn R1 so that V-out decreases, until it just equals zero. Now, measure VGS (it will be less than zero). As mentioned earlier, the frequency counter design requires a VGS (off) between -1.5 V and -3.5 V. Pick an MPF102 in this range closest to -2.5 V. You may have to test a handful of FETs to find one in the appropriate range. If you don't have any luck with your batch of MPF102s, you may want to try some 2N4416 FETs. The 2N4416 has a maximum VGS (off) of -6 V.

Power Supplies

Five volts are supplied to the circuit through regulator U6. Diode D3 provides reverse polarity protection of the

Figure 1A. The input stage and power supply.



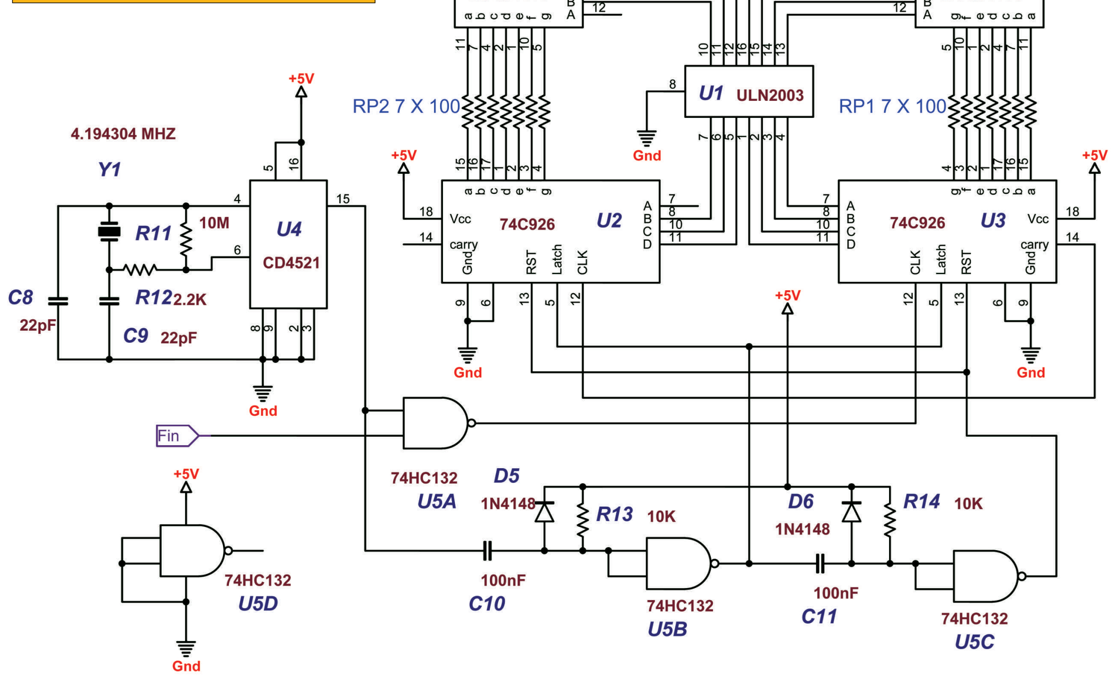


Figure 1B. The digital counting and display stages.

input voltage. C6 and C7 are bypass capacitors (shorting AC signals on the power supply to ground). C6 effectively shorts low frequencies to ground, but its ESR (effective series resistance) is too high for higher frequencies. C7 is more capable at shorting higher frequencies to ground. R10, in series with the 9.1 V Zener diode D4, provides a stable 9.1 V supply for the input stage. The maximum current drawn by this stage is around 8 mA. To determine R10, divide the voltage drop across R10 by double the current and solve for the resistor. In our example, the math equation is:

$R = (12\ V - 9.1\ V)/(.016\ A) = 180\Omega$

Clock

The reference clock is composed of Y1 and U4. U4 is a 24-stage frequency divider. For this design, the output of the counter needs to have a period of two seconds. The frequency at the output of U4, pin 15, is 1/8388608 multiplied by the clock frequency. Crystal Y1 supplies a stable 4.194304 MHz signal. The product of both therefore gives an output frequency of 0.5 Hz (equivalent to a two second period) at U4, pin 5.

The crystal oscillator circuit configuration with U4 is called a Pierce oscillator (also known as a parallel resonant crystal oscillator). R11 is connected across an inverter internal to U4. This causes the inverter to operate in its linear region and amplify the natural resonance of Y1.

Counter

The 74HC926 parts (U2 and U3) are four-digit counters, with reset and latch. The frequency clock is connected to U3, and the carry of U3 is connected to the clock input of U2. The latch and reset pins of U2 and U3 are tied together. This forms an eight digit counter. U1 is a Darlington transistor array, which drives the common cathodes of DISP1 and DISP2. Note that there are only seven Darlingtons in U1. This is all that is needed because the frequency counter's maximum count is 1 MHz. The digit in the 10 MHz place has no driver transistor and is not illuminated.

Figure 2. The VGS test circuit

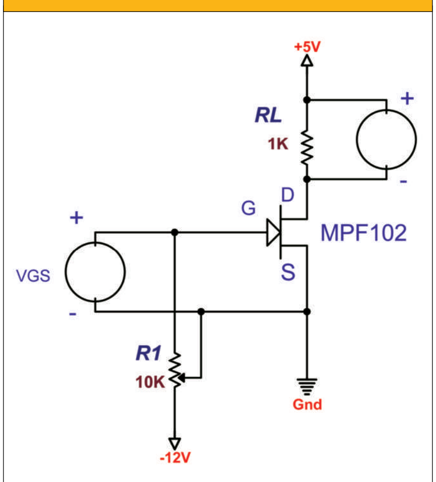
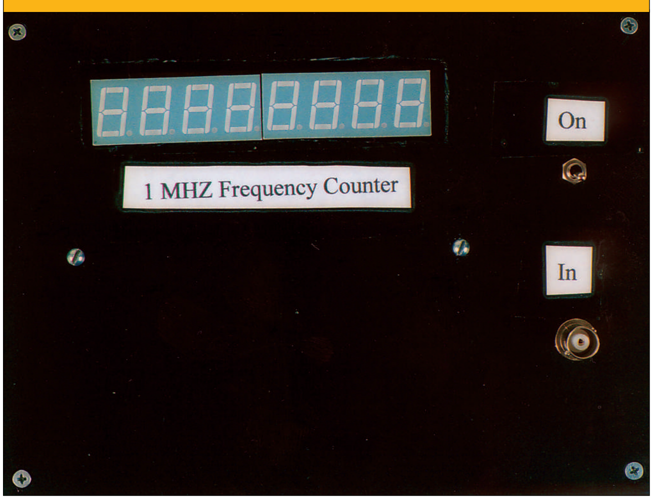


Figure 3. The prototype was built in a project box.



Since the period of the clock at U4, pin 15, is two seconds, the signal is high for one second and low for one second. The clock input of U3 is the NAND (U5A) of the front end frequency output and U4, pin 15. When U4, pin 15, is high for one second, the output of the NAND (U5A) provides active low pulses for each pulse of the input frequency. The clock input of U3 is active low. Because the input frequency is NANDed with a one second pulse, the frequency is simply the number of clock pulses that occur in that one second duration.

The output of the front end amplifier is capacitively coupled through C8 to the input of U5, pin1. This pin has a DC bias in the center of its hysteresis range. When the AC voltage at this pin exceeds the threshold voltages — typically spaced 1.5 V apart — the output is a square wave. U5B and U5C are used as inverters, thereby eliminating the need for another IC. D4 clamps the input voltage of U5B to +5 V when the input to capacitor C10 makes a low to high transition. D5 protects the input of U5C in a similar way.

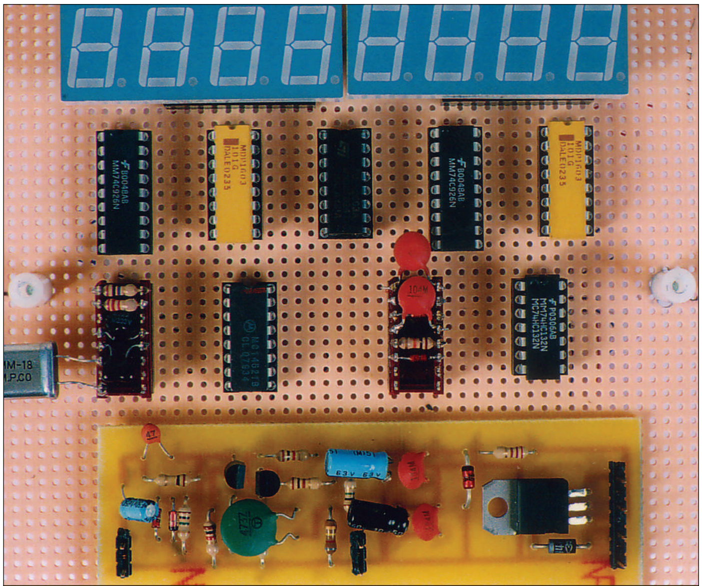


Figure 4. Wirewrap construction is sufficient for the counter.

As mentioned earlier, internal to each 74HC926 is a four digit decimal counter connected to a latch. When the output of U4, pin 15, goes low, a short high pulse appears at the output of U5B, pin 6. This clocks the latch input for the eight digit counter, which loads the display latch with the current counter value. When the output of U5, pin 6, goes low, the output of U5C is also a short high pulse. This pulse resets the counter. The counter will count the new frequency the next time U4, pin 15, goes high.

Parts List

Resistors (all 5%, 1/4 W)		C8, C9	22 pF 5% silver mica
R1	100K		
R2, R8	1M	**Semiconductors**	
R3, R4, R7	1K	D1, D2, D5, D6	1N4148
R5	100Ω	D3	1N4002
R6, R13, R14	10K	D4	1N4739A
R9	820K	Q1	MPF102
R10	180Ω	Q2	2N3906
R11	10M	U1	ULN2003
R12	200Ω	U2, U3	74C926
RP1, RP2	7 X 100Ω DIP network	U4	CD4521
		U5	74HC132
		U6	LM7805
		DISP1, DISP2	MSQ6441C
Capacitors			
C1	1 µF 63 V	**Miscellaneous**	
C2	47 pF	Y1	4.194304 MHz crystal
C3	47 nF	S1	SPST switch
C4	1 µF 50 V	J1	BNC female jack
C5, C7, C10, C11	100 nF 50 V	J2	3.5 mm jack
C6	10 µF 50 V		

If the input to the front end of the frequency counter is left floating (no input signal), the counter may display essentially random frequencies. It is important to remember that, when measuring square waves with amplitudes greater than approximately 4 V, the threshold detector U5A may falsely trigger, resulting in incorrect frequency readings. To avoid incorrect results, use a 10X scope probe when taking measurements above 4 V and a 1X probe when measuring amplitudes less than 4 V.

Construction

When I assembled the unit, I used a PCB for the input stage and power supply. The rest of the circuit was wire-wrapped. The size of the circuit board is 4.5" X 5.5" and is mounted in a RadioShack project case (part number 270-1809). If you need it to be portable, there is still enough room inside for a 12 volt battery holder (eight AA cells).

Have fun building and operating the 1 MHz frequency counter. **NV**

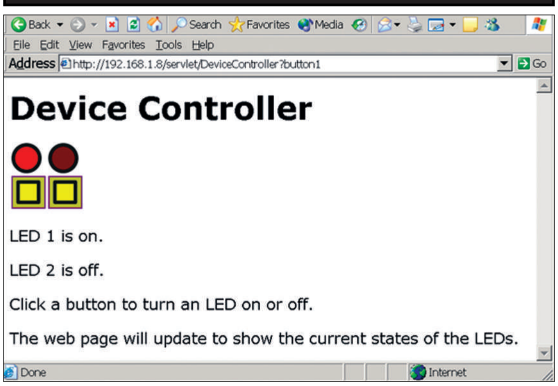
Control Your Devices From A Web Page

Of all of the millions of pages on the web, most are hosted by large servers or, at minimum, desktop PCs, but these aren't the only computers that can function as web servers. Even very small devices can serve web pages on request, including pages that display real-time information and respond to user input. The pages can either be available within a local network or an Internet connection can be added to make the pages available to anyone on the Internet.

The Device Controller described in this article is a small circuit board that controls external circuits and also functions as a web server. Users can access a web page to monitor and control the Device Controller's circuits. The Device Controller is based on a TINI module, which contains a CPU (central processing unit), networking support, and a Java runtime environment which enables the TINI to run Java programs. The TINI was developed by Dallas Semiconductor, a subsidiary of Maxim Integrated Products. The Device Controller's web page displays a virtual control panel (Figure 1). From this page, users can click buttons to turn two LEDs on and off. After clicking a button, the browser's web page updates to match the states of the LEDs.

In a similar way, you can program a TINI to monitor and control other circuits or processes, use a web page to enable users' data requests from the TINI, and control the TINI's circuits.

FIGURE 1. The Device Controller's web page is a virtual control panel that enables users to toggle LEDs on the TINI.



About the TINI

Two options for the TINI module are the DSTINIm400 ($67.00) from Dallas Semiconductor (Figure 2) and the TStik ($99.00) from Systronix (Figure 3). The CPU in both boards is a Dallas Semiconductor DS80C400 Network Microcontroller. Each module plugs into an evaluation board that contains components and connectors for a power supply, RS-232 serial port, and Ethernet. The TStik has an on-board Ethernet transceiver, while the DSTINIm400's Ethernet transceiver is on the evaluation board (DSTINIs400). Creating the Device Controller software, compiling it, and deploying it to the TINI requires a variety of software tools. All are free downloads.

The TINI Software Developers Kit (SDK), available from Dallas Semiconductor, includes the TINIOS operating system and the Java Virtual Machine (JVM) that executes Java programs in the TINI. Dallas Semiconductor also provides the JavaKit utility for configuring the TINI over its RS-232 serial port.

To compile Java programs for a TINI, you can use just about any Java compiler and Java development system, including the compiler in the free Java Development Kit (JDK) from Sun Microsystems. I use Borland's JBuilder environment, which includes a compiler and graphical interface for developing. A free Personal Edition is available. The Ant build tool and the TINI-specific add-on, TiniAnt, are useful for compiling and deploying code to the TINI.

A Java application, called a servlet engine, enables the TINI to

Media

Go

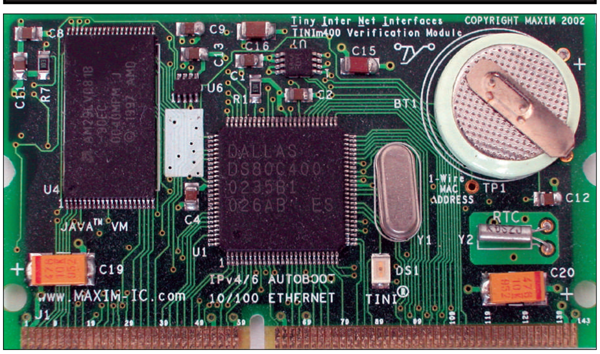
BY JAN AXELSON

run Java programs, called servlets, which can serve web pages that contain real-time information and respond to mouse clicks and other user input. The servlet engine I used for the Device Controller is Shawn Silverman's Tynamo web server, which is free for personal use.

My website at **www.Lvr.com** contains the complete DeviceController servlet code and instructions for running it. For loading files into the TINI and testing the web server on a network, you'll need a PC with an RS-232 serial port and an Ethernet network port.

Why use Java? The Java language is designed from the ground up for use in networking applications and the support built into the TINI's software greatly simplifies network programming. If you're not an experienced Java programmer, an introductory text will get you started. The TINI supports an older, simpler, but still very capable, JDK distribution (1.1.8). If you prefer to program in C instead of Java, my website also has a Device Controller project written in C for Rabbit Semiconductor's RabbitCore modules.

FIGURE 2. Dallas Semiconductor's DSTINIm400 module contains a DS80C400 Network Microcontroller and can run Java programs.



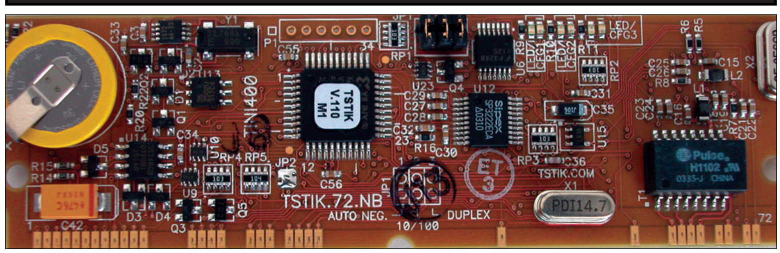
The Web Page

Listing 1 is the HTML source code of the page a browser might receive on requesting the Device Controller's web page. The text between angle brackets (<>) contains HTML code that tells the web browser how to display the text and images on the page.

The page includes four images. Ledon.gif and ledoff.gif are images of lit and unlit LEDs. The images reflect the states of the Device Controller's LEDs when the page was requested. The other two images are identical switches, or buttons (button.gif), which users click to toggle the LEDs.

When a user clicks a button's image, the browser's computer uses the HTTP (hypertext transfer protocol) to send a GET request over the network to the Device Controller. If the user clicks the first LED's button, the request contains the text /servlet/DeviceController?button1. The /servlet/DeviceController portion of the request tells the Device Controller to run the DeviceController servlet. The text following the question mark tells the Device Controller

FIGURE 3. Systronix's TStik also contains a DS80C400 Network Microcontroller and uses the popular 72-contact SIMM connector.



LISTING 1. The HTML code for Figure 1's web page includes links to images that match the states of the LEDs.

```
<html>
<head>
  <title>Device Controller </title>
</head>

<body>
<h1> Device Controller Demo</h1>

<table>
<tr>
  <td><img src ="ledon.gif" ></td>
  <td><img src ="ledoff.gif" ></td>
</tr>

<tr>
  <td>
  <a href="/servlet/DeviceController?button1">
    <img src="button.gif"></a>
  </td>
  <td>
  <a href="/servlet/DeviceController?button2">
    <img src="button.gif" ></a>
  </td>
</tr>

</table>

<p>LED 1 is on.</p>
<p>LED 2 is off.</p>
<p>Click a button to turn an LED on or off.</p>
<p>The web page will update to show the current states of the LEDs.</p>

</body>

</html>
```

LISTING 2. The servlet's doGet() method services HTTP requests for the web page.

```
/**
   * Responds to HTTP GET requests.
   *
   * @param request the HTTPServletRequest object
   * @param response the HttpServletResponse object
   *
   * @throws ServletException
   * @throws IOException
   */
  public void doGet(HttpServletRequest request, HttpServletResponse
response)
      throws ServletException, IOException
  {
  //The query string sent by the client tells which button
  // was clicked on the web page.
    String query = request.getQueryString();

    // Read the current state of the LEDs (0=on, 1=off).
    // and toggle the LED named in the query string.
    boolean led1On;
    if ("button1".equals(query)) {
      System.out.println("Button 1 was clicked");

      // Toggle the LED.
```

Listing 2. continued ...

```
 led1On = toggle(led1);
   } else {

     // Don't toggle the LED.
     // Read the LED's state and set led1On true if the state is 0
     // (on) and false if the state is 1 (off).
     led1On = (led1.readLatch() == 0);
   }

   boolean led2On;
   if ("button2".equals(query)) {
     System.out.println("Button 2 was clicked");

     // Toggle the LED.
     // A logic low turns the LED on.
     led2On = toggle(led2);
   } else {

     // Don't toggle the LED.
     // Read the LED's state and set LED2 On true if the state is 0
     // (on) and false if the state is 1 (off).
     led2On = (led2.readLatch() == 0);
   }

   // Set the images and text to match the LEDs' current states
   // If led1State (led2State) is true, LED1 (LED2) is off.
   // If led2State (led2State) is false, LED1 (LED2) is on.
   String led1Image;
   String led1State;
   if (led1On) {
     led1Image= "/ledon.gif";
     led1State = "on";
   }
   else {
     led1Image = "/ledoff.gif";
     led1State = "off";
   }

   String led2Image;
   String led2State;
   if (led2On) {
     led2Image= "/ledon.gif";
     led2State = "on";
   }
   else {
     led2Image = "/ledoff.gif";
     led2State = "off";
   }

   // Return the web page to the client.
   SendWebPage (response, led1Image, led2Image,
             led1State, led2State);

 } //end doGet
```

which button the user clicked (button1 or button2).

Serving the Web Page

On receiving a request to run the DeviceController servlet, the TINI executes the doGet() method found in Listing 2. One of the parameters passed to the method is

an HttpServletRequest object that contains information about the request. If the user has clicked a button, the object's getQueryString() method contains either "button1" or "button2" to indicate which button was clicked.

If the query string contains button1 or button2, a call to the toggle() method in Listing 3 toggles the state of the corresponding LED. Port bits on the DS80C400 control the LEDs. Led1 is controlled by Port 5, bit 4, and led2 is controlled by Port 5, bit 5. Figure 4 shows the circuits.

On the DSTINIs400 board, the bits are accessible from header J21. On the TStik, the bits are contacts 29 and 30 on the SIMM connector. I chose these bits, in part, because they're easily accessible. The bits also function as part of the SPI interface, which isn't available if you use the bits to control the LEDs. You can program the TINI to control any other I/O bits or peripherals you wish.

In the servlet code, led1 and led2 are BitPort objects in the TINI-specific class com.dalsemi.system.BitPort. The class's readLatch() method returns the last value written to a bit. The set() method sets a bit's value to 1 and the clear() method sets a bit's value to 0.

In Listing 2, after toggling the requested LED, the TINI sets the values of four variables that display the states of the LEDs as images and text on the web page. The variables led1Image and led2Image each contain a file name ("ledon.gif" or "ledoff.gif"), depending on the state of the corresponding LED. In a similar way, the led1State and led2State variables each contain the text "on" or "off."

A call to the application's SendWebPage() method sends a web page that displays images and text that match the states of the LEDs on the TINI. A series of out.print statements writes the web page's contents to the ServletOutputStream object out. The browser that requested to run the servlet receives the web page in an HTTP response.

This statement in the SendWebPage() method sends the contents of the page's <head> section, which contains the page's title:

```
out.print("<head><title>DeviceController</title>
</head>"
```

In a similar way, out.print statements send the rest of the HTML code that makes up the web page.

In sending the page, the servlet inserts the file names and text that match the states of the LEDs. This statement places the contents of the led2Image variable (either "ledon.gif" or "ledoff.gif") on the web page:

```
out.print(led2Image);
```

This statement places the contents of the led1State variable (either "on" or "off") on the web page:

```
out.print (led1State);
```

LISTING 3. The servlet's toggle() method toggles the LED at the named port bit.

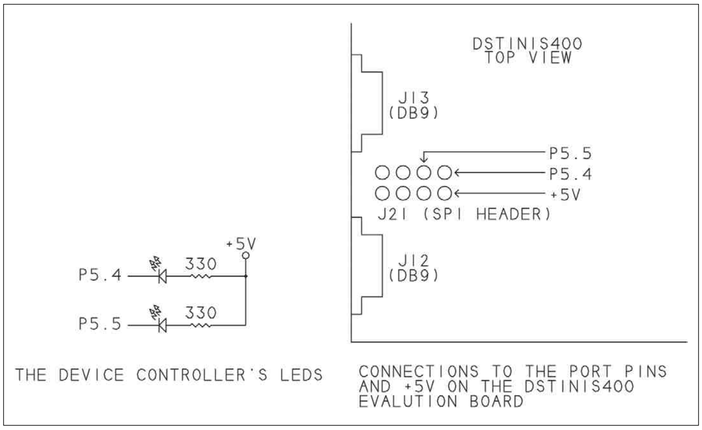
```
/**
 * Toggles the specified bitPort bit and returns the new state.
 *
 * @param bitPort a bit that controls an LED.
 */

private static boolean toggle(BitPort bitPort) {
  if (bitPort.readLatch() == 0) {

    // If it's 0, set the bit to turn the LED off and return false.
    bitPort.set();
    return false;
  } else {

    // If it's 1, clear the bit to turn the LED on and return true.
    bitPort.clear();
    return true;
  }
} // end toggle
```

FIGURE 4. A DSTINIm400 or TStik can control these LEDs.



Resources

Ant
(Ant build tool)
www.jakarta.apache.org

Borland
(JBuilder Java environment and compiler)
www.borland.com

Dallas Semiconductor
(DSTINIm400 module)
www.dalsemi.com

Rabbit Semiconductor
(RabbitCore modules)
www.rabbitsemiconductor.com

Sun
(Java Development Kit)
www.java.sun.com

Systronix
(TStik module)
www.systronix.com

TiniAnt
(TINI add-on for Ant)
tiniant.sourceforge.net

Tynamo
(TINI web server and servlet engine)
www.tynamo.com

Running the Web Server

Running the servlet requires a series of steps to build the application webserver.tini, deploy webserver.tini and related files to the TINI module, and run the application. The webserver.tini file contains the code for both the Tynamo web server and the DeviceController servlet.

These are the steps to follow:

1. Download the needed files. The DeviceController files are in devicecontroller.zip, available from **www.Lvr.com** The archive file contains the HTML file DeviceController_readme.htm, which has links to the other files required to build and deploy the Device Controller. Download these as well.

2. Building and deploying webserver.tini uses several configuration files. These are included in devicecontroller.zip. You must edit two of these files with information specific to your system.

The build.properties file contains the locations of the TINI SDK and the DeviceController servlet. Edit these lines to match the locations on your development PC:

```
# The location of the TINI SDK:
tini.path=/tini1.11

# The location of the servlet (DeviceController.java):
src.paths=/myservlets
```

Use forward slashes (/) as separators in the paths, even under Windows.

The deploy.properties file contains information about the TINI. Edit these lines to match the information for your TINI:

• The TINI's IP address:

```
deploy.server=192.168.1.9
```

• The TINI's user ID and password:

```
deploy.userid=root
deploy.password-tini
```

You can view and set the TINI's IP (Internet protocol) address using the TINI's ipconfig command. In JavaKit, type ipconfig to view the current settings and type ipconfig help to view the options you can set.

3. To build webserver.tini, run the Ant build tool by opening a command-prompt window on your development PC, changing to the directory where you stored the Tynamo download, and entering ant on the command line. The Ant tool uses the information in the configuration files to find out what to build and where to find the files.

4. Copy the files ledon.gif, ledoff.gif, and button.gif to the http-root directory in Tynamo's home directory.

5. To deploy the web server to the TINI, connect the TINI to your development PC via Ethernet. For a direct connection, attach a crossover cable directly from the TINI's Ethernet (RJ-45) connector to the PC's Ethernet connector. If your PC connects to an Ethernet repeater hub or switch, attach a straight-across cable between the TINI and an available port on the repeater hub or switch. At a command prompt on the development PC, type ant deploy. This causes the web server's files to transfer to the TINI via the File Transfer Protocol (FTP).

Making the Device Controller Available on the Internet

To access the Device Controller's web page from the Internet, you need to have an Internet account that permits hosting a server and network-security settings that enable the TINI to receive connection requests on port 80 (the default port for HTTP) or another port you specify.

Hosting a server may require a business account for Internet access. Accounts offered to home users typically forbid hosting servers because a server may draw more traffic than the provider can support at home-user prices. Some providers block incoming requests to open connections to port 80.

If the TINI accesses the Internet via a dial-up connection, you will, of course, need a phone line that's available to the TINI whenever you want the Device Controller to be on line.

It is wise to use a firewall to protect your computers that access the Internet. A firewall may be software running on a PC in the local network or a piece of dedicated hardware. If your TINI is behind a firewall, you'll need to configure the firewall to allow the TINI to receive incoming HTTP requests. One way to achieve this is to set up the firewall so that all requests to open a connection to Port 80 are routed to the TINI.

To access the TINI from the Internet, you need to know its public IP address. If you use a firewall with Network Address Translation (NAT), the firewall will use a single public IP address for all Internet communications, converting between the public and local IP addresses as needed. The firewall should have a configuration page that displays its public IP address.

From a browser, you access the Device Controller the same way you would in a local network, except that you must use a public IP address. If the address is 192.0.2.3, you would enter this in the browser's address box:

http://192.0.2.3/servlet/DeviceController

If the TINI's IP address has an assigned domain name, you can also access the Device Controller using the domain name:

www.example.com/servlet/DeviceController

In any case, it's best to check out the Device Controller on a local network before attempting to access it from the Internet.

6. To run the web server in Windows' Hyperterminal or a similar application, create a Telnet connection with these settings:

Host Address = the TINI's IP address
Port = 23
Connect = TCP/IP
Click Call to connect to the TINI and run the web server by entering this text in the Telnet window:

source web/bin/WebServer

When the server is running, the Telnet Window will display this text:

HttpServer: Server started.

The TINI is now ready to run the DeviceController servlet.

Accessing the Web Server

On a computer in the same local network as the TINI, in the address text box of a web browser, enter http://, followed by the TINI's IP address, /servlet/, and the servlet's name. For example, if the TINI's IP address is 192.168.1.9, enter this:

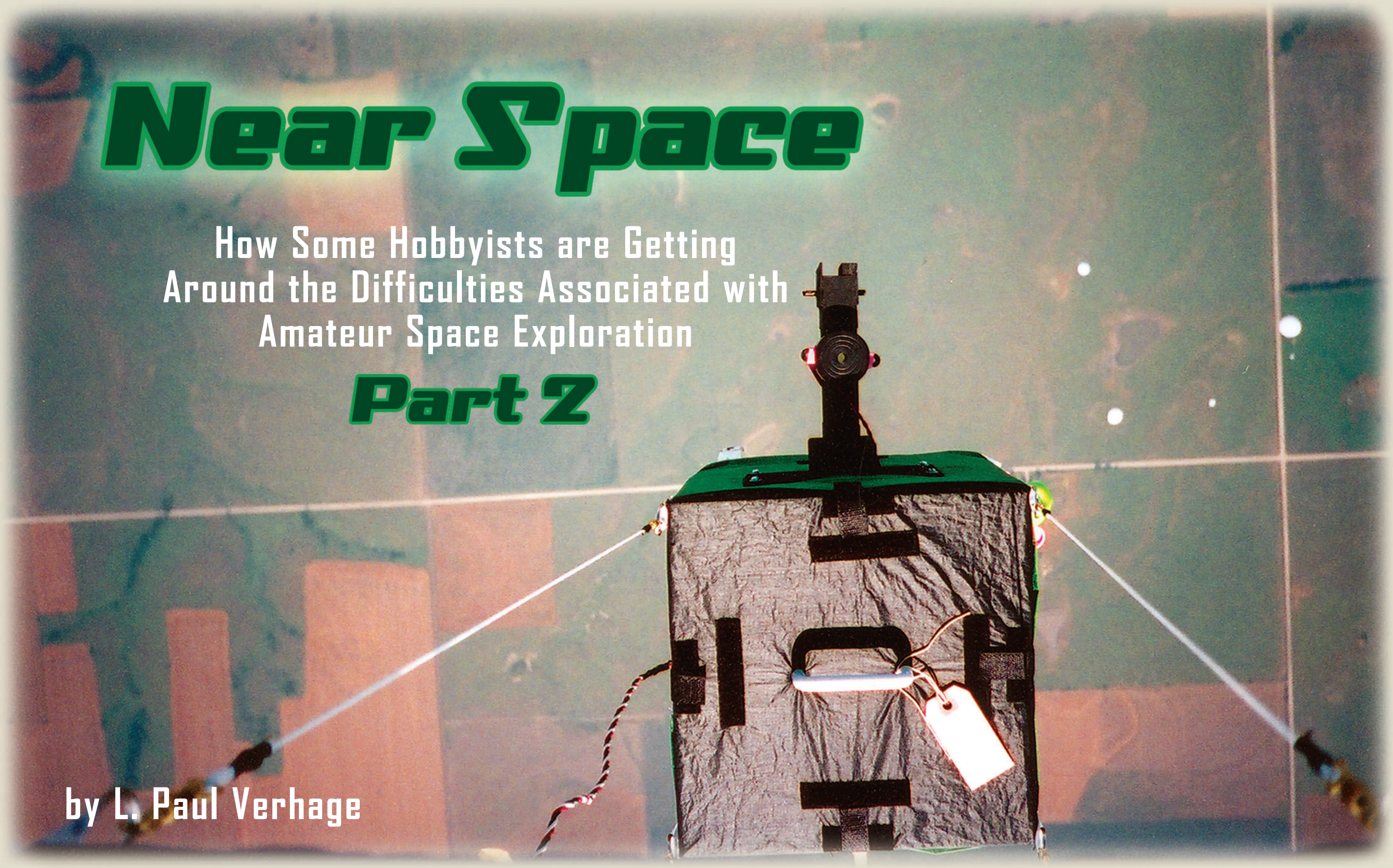
http://192.168.1.9/servlet/Device Controller

You should then see the Device Controller's web page with images and text that match the states of the LEDs on the TINI module. Click a button and the corresponding LED on the TINI will toggle and the browser will update with a new web page that reflects the change.

This basic application can serve as a template for TINIs that perform other monitoring and control tasks and serve web pages which enable users to view and control the TINI's activities.

My website (**www.Lvr.com**) has links to more documentation about the TINI and Tynamo web server and how to use them, as well as the complete source code for the Device Controller. **NV**

Jan Axelson is the author of *Embedded Ethernet and Internet Complete*, *USB Complete*, and other books about computer interfacing. For more about computer interfacing via Ethernet and other ports, visit Jan's website at **www.Lvr.com**



Near Space

How Some Hobbyists are Getting Around the Difficulties Associated with Amateur Space Exploration

Part 2

by L. Paul Verhage

Last month, we covered how hobbyists are getting around the high costs associated with spacecraft construction and launches. You learned a little about the structure of our atmosphere, the location of near space, and the conditions found there. Last month's article closed with a brief introduction to the near spacecraft. In that introduction, the parts of the stack were explained, along with their functions. This month's article discusses some of the benefits gained through beginning your own program and explains how you can build an inexpensive near spacecraft and use it in an amateur science project. Talk about an awesome science fair project!

Some of the Benefits of the Amateur Near Space Program

There are several benefits to creating your own amateur near space program. The first benefit is in the variety of fantastic experiments you can perform. There is also the program management experience you will gain and the inspiration that amateur near space can give. Finally, I see the sense of adventure that comes with each near space mission as an asset.

Amateur Science Experiments That Will Knock Your Socks Off

I have flown many experiments over my seven years and 44 flights in the hobby. Some of my best experiments are described in more detail below. The near space experiments I have flown so far have included recording images, measuring the cosmic ray flux, and making meteorological measurements in the stratosphere. I have also tested new designs and technologies and have let people communicate with one another through near space-based repeaters. Many of these experiments are also being flown by the active near space programs, which were listed at the end of last month's article.

Imaging With Cameras and Camcorders

Some of the most interesting results of a near space mission are in the images returned. Near space missions can record images of sunrise from deep within the stratosphere, the horizon during the day at various altitudes, or of the ground below. Each shows a unique perspective on our planet and its atmosphere.

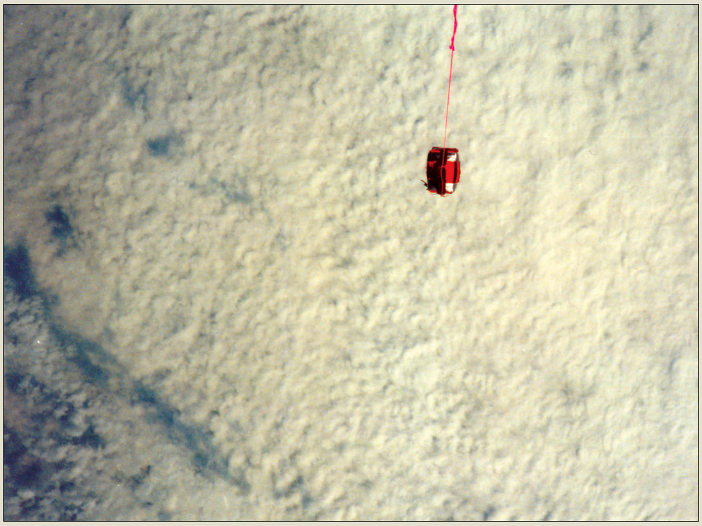
My video recording of dawn in near space shows an orange band of light hugging the eastern horizon that is topped by a narrow glow of electric blue. The rest of the sky remains pitch black. Beneath the light of dawn, the lights of Kansas City, which were over 100 miles away at the time, were bright. Instead of the sky turning orange at dawn, my videotape shows the ground turning orange. Finally, the Earth's shadow, which is noticeable from the ground, is much more distinct in near space.

Photographs of the horizon during the day show a

blue earth, curved horizon, and black space above. In my photographs, clouds over 100 miles away are visible. Cities and other human artifacts disappear; you would never guess that the earth was inhabited by humans from these photographs. Photographs of the horizon look like they were taken from orbit, so much so in fact, that twice now, photo lab technicians have asked me if I was an astronaut.

Depending on the altitude, photographs taken of the ground can span over 15 miles. Mountains take on a new perspective from near space. They flatten, so only their shadows and creeks indicate their existence. Missions over the years can record the seasonal changes in rivers and creeks. Entire towns and small cities are recorded in a single photograph, along with their roads, railroads, and rivers. You can see everyone's house from near space. The near spacecraft makes the ultimate amateur spysat!

Videotape taken during ascent records the gradual darkening of the sky and the increasing inability of the air to carry sounds. Specifically, high pitched tones drop out early, while lower pitched tones hang in there longer. Meteor observations are possible during night launches, if the module carries a low lux camcorder or image intensifier. In near space, even a full moon can't create the glare that prevents the observation of faint meteors from Earth.



An example of a reusable lunch bag-based airframe. Mark Conner's (N9XTN) module is seen being suspended about 10 feet below my module, which provides the tracking services for this flight. Tens of thousands of feet separate the clouds from this near spacecraft.

Cosmic Ray Studies with Geiger Counters

One of my favorite experiments is making cosmic ray measurements in near space. Aware Electronics manufactures an inexpensive, lightweight Geiger counter designed for laptop use. The RM-60 Geiger counter is about the size of a deck of playing cards and takes its power from a PC serial port. Its power and data cables are easily interfaced to flight computers.

The minimal weight, volume, and power requirements of the RM-60 make it the ideal Geiger counter for cosmic ray studies. The detection of a cosmic ray is signified with a short duration, five-volt pulse. Collecting cosmic ray data entails recording the current altitude from the GPS receiver, then the number of pulses over a specific time span.

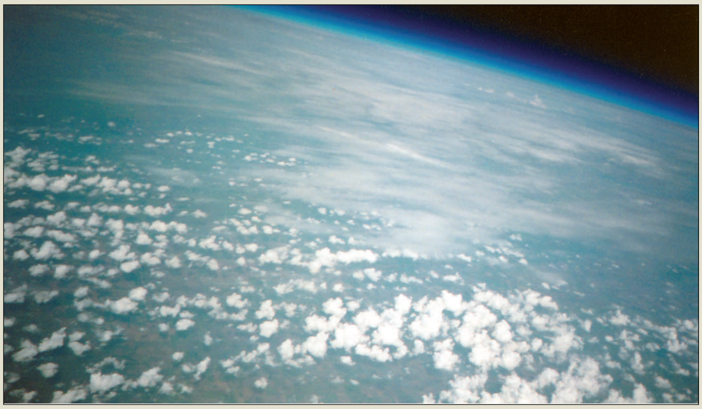
Most of the cosmic rays detected on the ground are secondary and not the original — or primary — cosmic rays from outer space. This is because primary rays create showers of secondary rays when they slam into nitrogen and oxygen molecules high in the atmosphere. However, near space is high enough that Geiger counters will begin detecting primary rays. Since the RM-60, combined with the flight computer, can detect a single cosmic ray, my missions into near space can detect a single atom that originated in another star.

Weather Stations

Do you want to know the air temperature, pressure, and relative humidity found in near space? If so, then launch a lightweight weather station. A pressure sensor will show that the atmospheric pressure decreases by a factor of two for every 18,000-foot increase in altitude. Aside from just measuring the current air temperature, a temperature sensor can also permit you to determine the lapse rate (the rate at which the air temperature changes with increasing altitude) and the stability of the troposphere. It also lets you determine the altitude of the tropopause and how its altitude and temperature change over the course of the year. A relative humidity sensor will show you how rapidly the atmosphere dries as altitude increases.

Don't forget the onboard GPS receiver, as it, too, is a part of the weather station. I use data from a GPS receiver to determine the direction and speed of the wind at various altitudes. With this data, I can measure the speed and altitude of the jet stream for myself. On near space missions, hobbyists make the same measurements that the National Weather Service does with its 100 daily radiosonde launches.

The Earth, photographed from an altitude of 86,000 feet. Sensors on this mission indicated that the air temperature was nine degrees Fahrenheit at the time. The distance to the horizon was calculated to be 360 miles. Beautiful clouds of fair weather cumulus, marching in rows, fill the scene.



Technology Testing

The air in near space is too thin to conduct a significant amount of heat to/from experiments. Instead of thermal contact with the air, the primary source of heat for exposed experiments is radiation transfer from the sun (unless heaters are added to the experiment). This is similar to the situation found in space and on the surface of most planetary bodies in our solar system.

Launching a piece of equipment on a near spacecraft to an altitude of 100,000 feet is a fantastic way to test its ability to function in a real space flight. In near space, equipment under test is exposed to a combination of cold temperature, low air pressure, and increased ultraviolet radiation. Tests performed at an altitude of 103,000 feet experience the same temperature and pressure found on the surface of Mars. If you include a camera or camcorder on the mission, then you will get images of the piece of equipment during its test with the earth's horizon in space as the backdrop. You may be able to get a sponsorship if a product logo is prominently displayed in the photograph.

Near Space Communications

Amateur radio communications with VHF and UHF radios (some of the most popular radios in the amateur radio community) are usually limited to their line-of-sight. In most cases, line-of-sight is only a few miles. With few exceptions, these kinds of radios don't communicate well with similar radios located over their local horizons. Repeaters — which are automated stations that retransmit radio communications — are usually located on either mountain tops or tall radio towers. They have more distant horizons and can extend the range of VHF and UHF radios to a few tens of miles.

A near spacecraft makes a fantastic repeater platform. Under ideal conditions, a repeater on a near spacecraft at an altitude of 100,000 feet lets two individuals 800 miles apart communicate with one another using inexpensive handheld radios. You can see that a near spacecraft with a radio repeater imitates a communication satellite. In this case, however, it's much cheaper and it's your communication satellite!

Program Management Experience

Aside from the experiments you can perform once your near spacecraft is on station, there are additional benefits that you can gain from an amateur near space program. For one, you can gain experience in program management. There are several levels of management in an amateur near space program. At the simplest level is the management of a single mission. This means matching payloads to the physical, electrical, and logical characteristics of the near spacecraft.

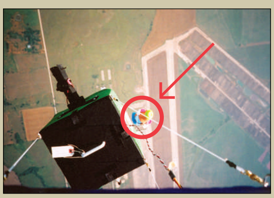
The next level of management is the planning needed for an entire mission. At this level, you are managing flight readiness reviews, chase frequencies, launch site selection, and the driving course for the chase and recovery crew. There are also flight predictions to be made. Flight predictions usually begin a week in advance of the launch. They are made from weather reports, with the help of software available from the EOSS website (**www.eoss.org**). You can see that launch week is a very busy time for the launch manager.

Beyond the management of a single mission is the management of an entire amateur near space program. Such a program can easily launch in excess of four flights per year. It takes someone with management skills to plan missions over the years. Funding and educational outreach are some of the important issues which require high level management. Managing a near space program is similar to managing a real space program, except that its cost and scale are accessible to the hobbyist.

Inspiration

Many people are inspired by visiting locations like the Grand Canyon. A subset of these people will go on to gain deeper inspiration by actually hiking through the landmark. Just like the Grand Canyon,

A Luckless Idaho Airborne Commando, Captured by a Kansas Farmer



Mr. Potato Head bravely parachuted from near space during Idaho's attempt to invade Kansas. Riding the TVNSP (Treasure Valley Near Space Project) near spacecraft and carrying a camouflage parachute, he made this airborne assault on the farmlands of the Midwest during Great Plains Super Launch 2002.

Unfortunately, before Mr. Potato Head could complete his secret mission, he was captured by a local farmer and turned over to the Dickinson County Sheriff. The sheriff's department released these photographs of Mr. Potato Head, which chronicle the events following his capture.

Here we see the grim, but determined, Mr. Potato Head getting his mug shot. All the while, he was no doubt planning his eventual escape to freedom among the peace-loving people of Idaho.

Finally, Mr. Potato Head was thrown behind bars on a charge of trespassing. It's believed that he never divulged the true nature of his secret mission.

What lesson did Idahoan near space explorers learn from this sad event? They learned that you don't parachute into Kansas from an altitude of 50,000 feet because Kansas farmers really hate that. For GPSL 2004, Idaho will instead attempt to drop propaganda leaflets from near space upon the unsuspecting masses of Kansas.

seeing or hearing about near space will inspire many people. A subset of these people will go on to develop deeper inspiration by designing and launching an experiment into near space.

This experience and inspiration may encourage young people to become scientists or engineers. At a minimum, they will develop a better understanding and appreciation of science and engineering. Near space is a hands-on source of inspiration that lets people see and experience work in a space-related field. If you decide to begin an amateur near space program, be sure to show it to the public. Share it at science fairs and on special days like Space Day, Astronomy Day, and Field Day.

Adventure

There is one last benefit I can think of; in addition to amateur science, program management, and inspiration, there's the adventure. After liftoff of the stack (the near spacecraft and its launch vehicle), crews will begin their chase. A rough idea of the near spacecraft's landing zone is known because of flight predictions; however, the details of the chase and recovery are not known in advance.

Driving over obscure back roads and through tiny towns can be great fun, especially when your convoy is equipped with a dozen antennas, several laptops, and radios. Try stopping at a gas station and waiting for a balloon burst while constantly looking up at the sky — this kind of behavior makes the locals wonder what you're up to. When you show them a tiny dot in the sky and explain that it's your balloon at 90,000 feet, you will amaze most of them.

The last part of the chase, approaching the landing zone, creates a high level of excitement as you attempt to reach the near spacecraft before it lands. Be aware though, the near spacecraft is under no obligation to land close to the road. Depending on the location of the landing zone, your recovery crew may end up going for a hike to recover the near spacecraft and launch vehicle. Most of the time this hike is fun, but it can also be a challenge, so be prepared.

After having recovered the near spacecraft, your crew will usually drop off their film and head to lunch. Lunch is a time to share stories of past and present adventures. Don't be too surprised if you turn some heads at the restaurant with your stories. You'll also realize that you probably did more that morning than most people will do all weekend.

Final Comments

The cost of a near space program is low enough that almost anyone can get a foot in the door. An amateur near space program is not a dead-end activity. Just testing materials and their applications to near space is an example of the important work that still needs to be done. Best of all, the results of these tests are applicable to spacecraft engineering and construction. With more and better sensors and electronic devices becoming available to the public, you'll always have new experiments to perform in near space. If space exploration appeals to you, but the cost is prohibitive, then consider beginning your own poor man's space program. Where

Six stacks are about to be launched. You'll actually count eight balloons because of the red piball (pilot balloon) and the extra balloon on Don Pfister's stack. The piball was launched by EOSS to gauge wind speed and direction before GPSL 2002 launched.

The author lifting the module of one of his near spacecraft. The second module is green and can partially be seen in the grass. The "Remove Before Flight" tag is a reminder for launch crews to open the camera before launching the mission. (Photo courtesy of Shari Conner, K9XTN)

else can you practice what it takes to build and launch a spacecraft?

This article can't give you enough information to begin your own near space program, so please consult one of the near space groups for help. Otherwise, check with Parallax for my upcoming book on creating and managing your own poor man's space program with the BASIC Stamp 2p.

You can begin your amateur near space program right now by studying for your amateur radio license (if you don't already have it). Several businesses, including some of those advertising in *Nuts & Volts*, sell the book, *Now You're Talking*. This book is one of the best study guides for the amateur radio test. Are you worried about the Morse code test? Don't worry, because you are no longer required to know Morse code. Consult the ARRL website (**www.arrl.org**) for the location of the amateur radio club closest to you. Your local amateur radio club is your best resource for earning your ticket.

Onwards and Upwards! **NV**

About the Author

L. Paul Verhage is an electronics teacher at the Dehryl A. Dennis Professional Technical Education Center in Boise, ID. He began working in the amateur near space field in 1994 and has accomplished over 40 missions. His book, *Amateur Near Space with the BASIC Stamp 2p*, will be published this year by Parallax.

The descent of a near spacecraft. This one may belong to Mark Conner's (N9XTN) near space program, NSTAR. What's left of the balloon is visible to the left of the parachute. Flight predictions allowed chase crews to be close enough to the descending mission that Doug Eubank (KA0O) of NSTAR was able to get this photograph (and three other ones that morning — amazing).

Announcing *N&V's* Near Space Column

Part 1 of L. Paul Verhage's near space article in the February Nuts & Volts generated an overwhelming response from our readers. In light of this, we have invited Paul to become our monthly columnist on the subject of near space. His column will begin in the April issue.

Electronics Showcase

Special products and services for the electronics enthusiast.

News Bytes

On the Ground, But Off the Grid.

In November 2003, the first commercial building to receive 100% of its energy needs from alternative sources was fully constructed and functioning. The 26,000 square foot Michigan Alternative and Renewable Energy Center (MAREC) became the first commercial project in the world to integrate fuel cell technology, a heat recovery system for heating and air conditioning, solar photovoltaics, and a nickel metal hydride battery storage system.

MAREC uses two main elements for generating power: a fuel cell that can produce 250 kW of electricity from natural gas and a solar panel array on the roof that can deliver up to 30 kW, as well. Efficiencies as high as 60% are being achieved with centralized generation and heat recovery techniques. This says nothing of the optimized architecture of the building itself — daylight penetrates 90% of the occupied areas. This may be the future of small building design, should the squeeze of fossil fuels get tighter in the future.

So Much For Xenon.

If the Cree Corporation (**www.cree.com**) has its way, the end of this noble gas in consumer flash lamps is just around the corner. Cree, an advanced R&D company in Durham, NC, is well-known for its process to synthesize vast amounts of moissanite — silicon carbide (SiC) — for use in semiconductors, as well as gemology. Leveraging their expertise in crystal growth techniques, they recently announced the XThin® series of high output, white LEDs.

The XT-18, pumping out an amazing 18 milliwatts of optical power, is a germanium doped SiC substrate that supports an indium gallium nitride anode, producing a highly efficient solid state emitter. In the end, though, all this fancy chemistry and material science will make your next pocket-sized digital camera last longer on a battery charge ... and put diamonds in the eyes of your subjects.

The Wrong Trousers? Almost.

Sure, you thought Nick Park was making all that Techno-Trouser stuff up in Wallace and Grommit. Well, surprise, the engineers at Japan's Waseda University have been at this for a while. Specializing in walking machines, they've tuned their control system to actually carry a person atop a pair of walking legs!

The WL-16 (Waseda Leg, revision 16) weighs just over 100 lbs. and can carry slightly more than that as payload. The control system, powered by an 850 MHz Pentium CPU, calculates a ZMP (zero moment point) to stabilize the system as balance is transferred between feet in the gait. Steps can range from 100 mm to 300 mm each, limited by the extension of the linear actuators that form the leg.

The Waseda researchers envision their research as forming the basis for future mobility devices (walking chair vs. wheelchair), as well as equipping future robots to work effectively in environments designed for humans. Visit the *Nuts & Volts* website to see a video of this machine in action (**www.nutsvolts.com**) and the university website for more information (in Japanese) **www.takanishi.mech.waseda.ac.jp/parallel/index_j.htm**

Learn About Cyclic Redundancy Checks

CRC Detects Errors in Digital Data Communications and Can Encrypt Data

by Michael Kornacher

In our modern age, the importance of digital electronic data communications by telephone lines, through a modem, special high-speed lines, or over the airwaves by radio cannot be overstated. The transfer of information via these media is critical for the successful operation of government, military, business, and banking. Without this technology, our information age and the Internet would be impossible.

The reliability of data communications over distance is of the utmost importance because of the critical requirements of its users. If the medium cannot be relied upon for error-free performance, it is useless. The damaging effects that can compromise the system are noise, distortion, and interference. These three gremlins have the ability to turn a digital one bit message into a digital zero bit and vice versa. If this reversal of a bit occurs, then an error has crept in, possibly undetected. This scenario could be disastrous.

Since we cannot guarantee a perfect medium between a source transmitter and a destination receiver, some method to detect errors must be employed. Thankfully, there are some systems that can do this. Parity check and checksum are two ways, but they have limitations. Another method is a code called Cyclic Redundancy Check (CRC). CRC is a popular and powerful means to ensure that a transmitter and receiver can communicate data reliably, even in the worst of conditions. CRC is so well regarded that the Internet relies on it for error detection.

In this article, I will present a short course on CRC and supply the knowledge needed to implement simple digital electronic circuits to perform CRC. Later, I will present a modification to the concept, where a method of data encryption, along with the normal error-detecting feature, can be utilized.

Cyclic Redundancy Check is a code — or algorithm — that has three basic and endearing qualities: it provides extreme error detection capabilities, requires a minimum of hardware and software, and is easy to implement. These advantages can make the application of this system by hobbyists and hardware hackers a reality. I will demonstrate that CRC circuits are very easy to breadboard and utilize.

Parity check, checksum, and CRC all work by applying an algorithm to a message. This algorithm, or code, produces a binary value that represents the message in some digital logic way. This value is then appended to the end of the message before it is transmitted out. The receiver at the other end of the link receives the message and binary value combination, then applies the same algorithm to the message to produce its own binary value. The receiver compares the two values and, if they are equal, then the message was received correctly. If they are not equal, then the receiver tells the transmitter to retransmit the message.

The primary benefit of CRC is that it can detect more types of data errors than the other two methods. For instance, it can detect all single bit errors, all double bit errors, any odd number of errors, and most burst errors. Parity check, on the other hand, can only detect single bit errors, while checksum can detect all single bit and some multiple bit errors. Obviously, CRC is the most robust of the group.

Modulo-2 Arithmetic

In exploring the theory behind CRC, we will begin with a short lesson on modulo-2 arithmetic. Modulo-2 arithmetic is normal binary addition or subtraction, but is not concerned with carrying or borrowing, as in decimal

arithmetic. For those familiar with logic half adders, it's just the exclusive-OR logic operation. For example, adding, subtracting, and multiplying, respectively, are as follows:

```
  1111          1111           11011
+ 0110        - 0110          x 1101
  1001          1001           11011
                              00000
                             11011
                            11011
                            10101111
```

In short, to add the bits in the columns when there is an odd number of binary ones in a column, then the sum of that column is a binary one. If there's an even number of ones in the column, then the sum of that column is a binary zero. It's that simple. Modulo-2 long division, which we'll discuss next, is not so intuitive, but, by studying the examples, the steps will become clear.

Cyclic Redundancy Check

Cyclic Redundancy Check can be described in three ways: modulo-2 arithmetic (which I will continue with next), polynomial arithmetic, and digital logic circuits. Because of space limitations, I will not be able to present the polynomial arithmetic aspect, but we will look at some circuits. We will have to do some simple math; since we're just dealing with ones and zeros, hopefully it won't be too difficult.

In a transmitter, let us define message M as being m bits long. This m bit message will be divided, using modulo-2 long division, by a pre-defined binary pattern divisor P. The division, just like regular long division, will produce an r bit long remainder R known as the Frame Check Sequence (FCS). From now on, I shall refer to remainder value R as the FCS to prevent confusion with other remainders that will be discussed later. The r bit FCS will be appended to the end of the m bit message M to be sent out as the data transmission.

The previous paragraph has thus defined the philosophy employed in the transmitter. There are a few loose ends. The length of pattern P, therefore, must be r + 1 bits long. The number of bits of the FCS must be less than the number of bits of message M, or r < m.

The long division process can be done by either software or, as I will later show, by hardware. The division is the easiest to do in software, but hardware is much faster. To perform the division properly, message M must initially be padded with r zero trailing bits. At the end of the division process, the r zero bits will be replaced by r remainder bits to become the FCS.

The transmitter's pre-defined pattern divisor P is a code word or key that must be known by the receiver, too. The quotient produced by the division has no function in this scheme and is thus ignored. Incidently, though, the number of bits q of quotient Q will be the same as the number of bits of message M, or q = m. Later, I will show how the quotient can be used in a method of data encryption.

When the receiver receives the data — message M with the FCS — it divides this combination, in modulo-2, by the identical pattern divisor P that the transmitter used. If the remainder of this division is zero, then no errors crept into message M during transmission and the validity of the message can be ensured. The quotient of this division is, again, not used in this process and is also ignored.

With this much now known, see Example 1 for a reference regarding using modulo-2 long division. The remainder, 1110, is four bits long, but, since we know that the length of the remainder must be one bit less than the divisor for a total of five bits, we add a zero to the most significant bit (MSB) so it becomes 01110. The quotient, just for the sake of completeness, also has a zero added to the least significant bit (LSB), because its length must be equal to the message for a total of ten bits.

The FCS remainder R, 01110, is appended to message M, 1010001101, to become 101000110101110, which is transmitted. The receiver obtains the message and divides 101000110101110 by the same pattern P to produce, if there are no errors, a remainder of zero, as we will see in the modulo-2 long division shown in Example 2. Since the remainder is zero, no errors occurred during transmission and the message is valid and reliable.

Digital Circuits

Having now finished covering the fundamentals, you might be wondering how all this gets us to some practical logic circuits. The truth of the matter is that the mathematical division operations we just discussed can be represented by digital shift registers. In addition, the binary ones and

Example 1

```
                1101010110  <-Q
              _______________
P-> 110101|1000110100000  <-M
           110101
            111011
            110101
              111010
              110101
                111110
                110101
                  101100
                  110101
                   110010
                   110101
                     01110  <-R
```

Example 2

```
                1101010110  <-Q
              _______________
P-> 110101|101000110101110  <-M
           110101
            111011
            110101
              111010
              110101
                111110
                110101
                  101111
                  110101
                   110101
                   110101
                    00000  <-R
```

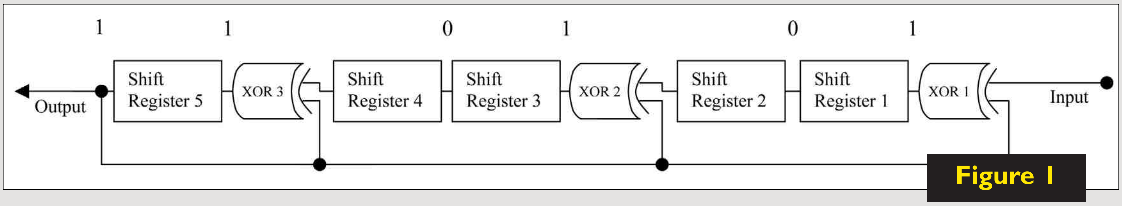


Figure 1

zeros of the pattern-divisor correspond to the presence or absence of a simple exclusive-OR logic gate.

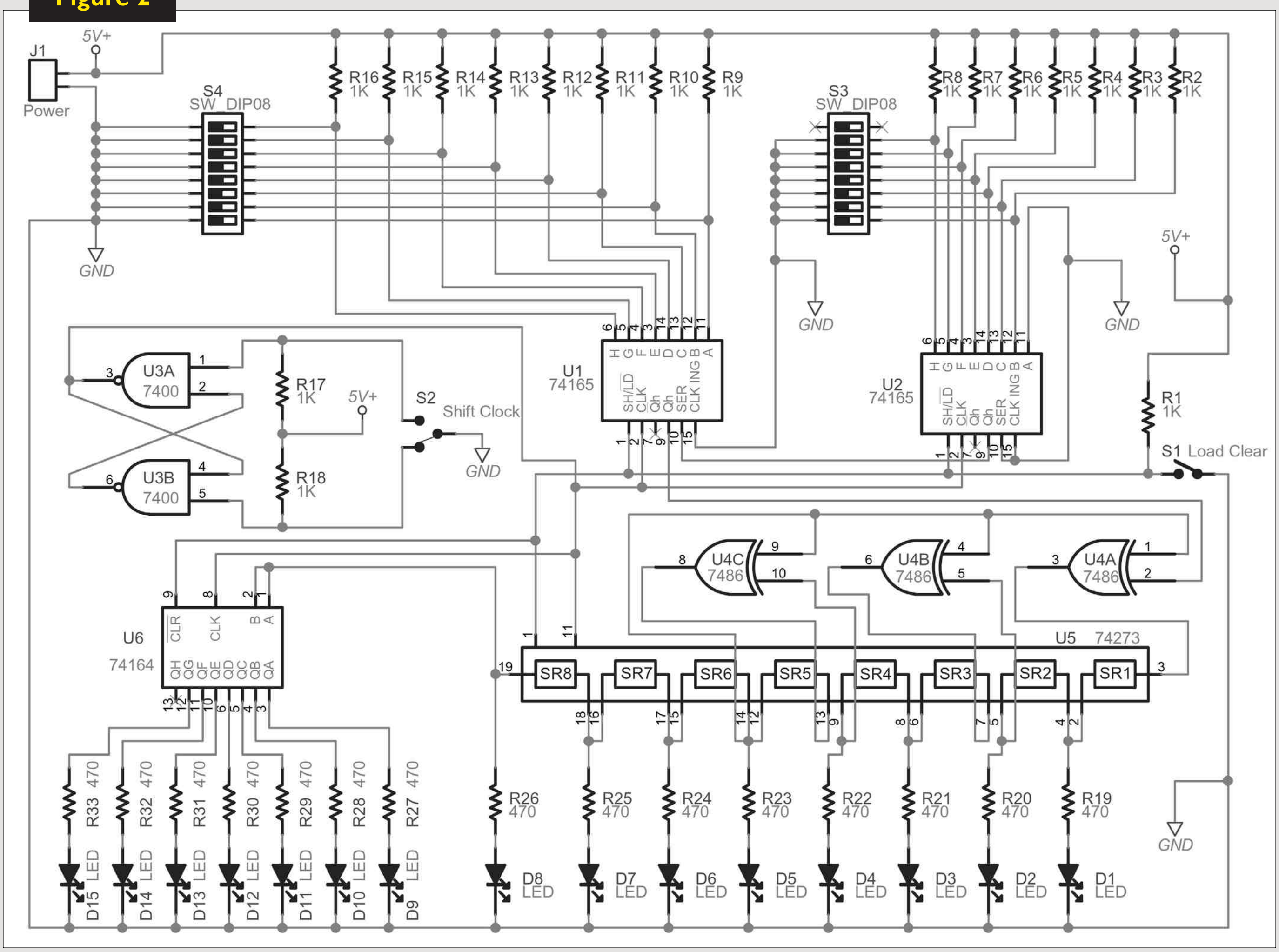
This information tells us how to build the circuit that will be the pattern divisor, which will generate the FCS used in CRC. A branch of error control code theory called cyclic codes is what we have been talking about previously. Fortunately, shift register circuits and exclusive-OR gate logic can imitate the function of modulo-2 math and cyclic codes.

To build the divisor circuit, the number of shift-registers and exclusive-OR gates needed is determined by the bits of the divisor pattern P. If we have j total number of bits in the pattern P, then we need j - 1 number of shift registers. And, if k is the number of binary one bits of P, then k - 1 will be the number of exclusive-OR gates needed.

Let us now present the schematic for the pattern divisor circuit in Figure 1. Please notice that this circuit uses a serial logic feedback arrangement. This will allow the serial data message to be divided in modulo-2 long division arithmetic. Also, a circuit usually has the input on the left and the output on the right, but here, I have reversed it to more closely resemble the convention used in writing binary numbers, where the MSB is on the left and LSB is on the right. This way, it will be easier to understand the connection between the two.

As you can see, it is relatively simple for this circuit to perform a long division operation in modulo-2 on serial data. The shift register chip I used for this project is a TTL 74273 and the exclusive-OR gate chip is a 7486. The 74273 has eight independent shift registers with a common clock and master reset. The registers can be connected together or have the exclusive-OR gates inserted in between,

Figure 2



according to where the one bits of the pattern are located.

Figure 2 is the schematic for the whole circuit I used to demonstrate the CRC principle. In the lower right is the divider circuit, just mentioned. On top is the circuit to input the message to be serially shifted through the divider circuit. It uses two 74165 eight-input parallels to serial shift registers. On the lower left is a 74164 serial to parallel eight-output shift register to hold and display the output data.

Example 3

```
          Q-> 1101010110
                  110101 <-P
              1101010110
             0000000000
            1101010110
           0000000000
          1101010110
         1101010110
         101000110101110

M-> (1010001101)(01110) <-R
```

There is a de-bounced switch to manually operate the shift-clock and another logic switch to simultaneously load the 74165s with the message and clear the registers of the 74273 and 74164 to zero. The LEDs will be used to indicate the states of the registers and values that we are interested in.

To make the circuit work, message M plus the padded five zeros — 101000110100000 — must be applied to the 74165s, as shown, by setting the input data switches high or low, accordingly. Then, to load the 74165s with the message and to reset the 74273 and 74164, the clear-load line must be momentarily brought low, then high. It is imperative that the registers are initialized to the zero state or our calculation will be wrong.

Next, it is a simple matter of toggling the shift-clock control to shift the message through the divider circuit until the quotient 1101010110 appears at the end of the 74164. The FCS remainder value 01110 will appear from the divider circuit, proving the operation of the transmitter's CRC circuit. Do not shift any further; any more shifting will corrupt the remainder. Since the message with the five zeros is 15 bits long, it should take 15 toggles of the shift-clock to move it through to the end.

This design would probably be very close to an actual transmitter circuit employed in a system. What I have not shown is that the FCS remainder value would be appended to message M in another circuit and then shifted out to be encoded in the format to be transmitted. This format would either be a modem for a telephone line or a modulator for a radio transmitter. I omitted this, as I only wanted to show how the basic divider circuit worked and what peripheral circuits were needed to accomplish that.

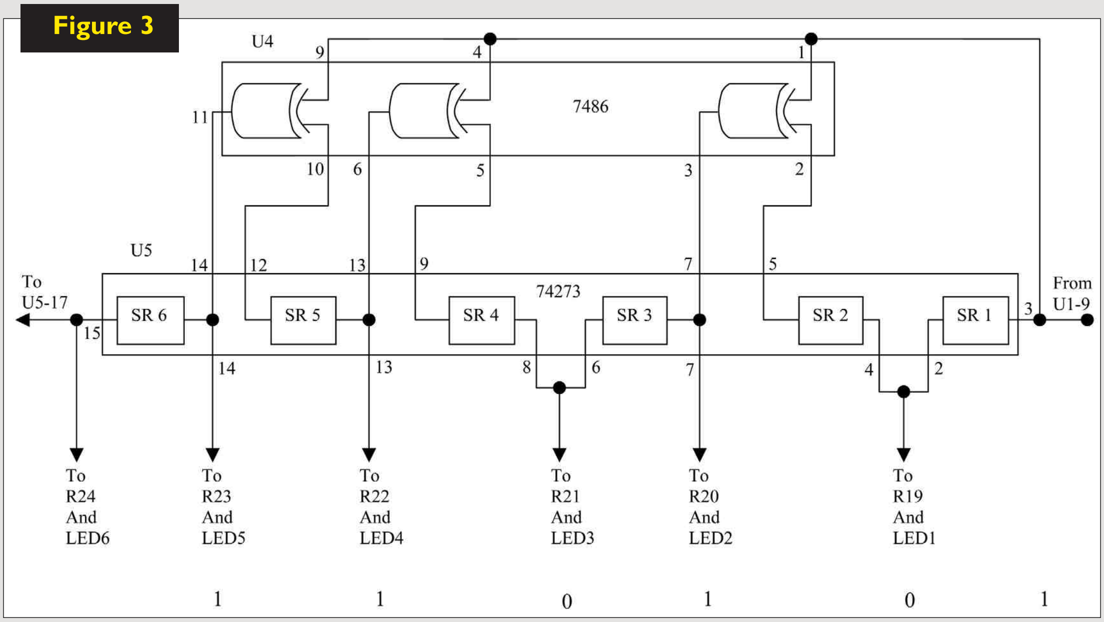
Another way of looking at this circuit is as if it was being employed at the receiver end, since both the receiver's divider circuit and the transmitter's divider circuit are identical. With this way of looking at it, the lower part of the circuit in Figure 2 would be the receiver and the top part of the circuit would simulate the transmitter. So, according to your point of view, the circuit could separately simulate both ends of a network.

With this in mind, if the five padded zeros appended to the message are replaced with the FCS value of 01110 and the clear-load is initiated, then, after toggling the shift-clock 15 times, the quotient will again appear at the output LEDs, but this time, the divider circuit will show a remainder value of zero (no LEDs illuminated), thus showing that the receiver received the message correctly, proving the CRC operation.

Data Encryption

If you will recall, I said that the long division process by the transmitter CRC circuit, which produced the FCS remainder, also produced the quotient Q. This quotient, as I said, being an unneeded byproduct of the process, was ignored. To implement a method of data encryption, this quotient can be utilized. Hence, instead of transmitting the message and FCS in the usual way, the quotient and FCS could be transmitted. The receiver, in turn, instead of dividing like before, would simply multiply the received

Figure 3



quotient value by pattern P in modulo-2 to produce the real message and, using the FCS in the normal way, check for any errors.

Thus, when the receiver would receive a message (quotient) and FCS, it could separate the two and store the FCS to be used for comparison later. After multiplying, the product of P and Q is M — the real message M, and, with this product, a calculated FCS value. This calculated FCS part could then be compared with the received and stored FCS. If they were equal, then the real message, which was just calculated, would be confirmed correct, valid, and reliable.

By sending the quotient and FCS as the data, if this encoded message (quotient) is intercepted, it cannot easily be deciphered without knowing the key, which is pattern P. Thus, the data could obtain a high level of security and privacy between the communicating sites.

Using our previous example, let us use Example 3 to confirm the multiplication arithmetic of the receiver. If the least significant five bits of the product in Example 3, which is the calculated FCS, are equal to the received FCS, then the message is valid. All that is needed for this concept to work is a circuit for the receiver to perform the modulo-2 multiplication, using the pattern P.

Figure 3 is the schematic of such a circuit. Notice that it is similar to the divider circuit, using shift registers and exclusive-OR gates, but now in a feedforward logic configuration. By rearranging the divider circuit in Figure 2 to be the multiplier circuit of Figure 3, the demonstration circuit can now verify the data encryption method. Load the 74165 chips with the quotient and FCS value, 110101011001110, toggle the shift-clock just 10 times, and watch the real message and calculated FCS, 101000110101110, appear at the LEDs.

Here, we only had to shift 10 times to get the 15-bit product (message and calculated FCS). Five more toggles of the shift-clock would shift in the actual FCS, but, unfortunately, the multiplier circuit would corrupt the FCS, so some minor modifications would be needed to be able to see the value. Just know that the transmitted FCS is present and waiting to be shifted in and received.

Now, I must confess that, although I do not know of any system that uses this particular method of data encryption, I have shown that it is a mathematically and electronically possible technique.

Conclusion

Although Cyclic Redundancy Check is not as advanced as the error correcting codes that are now available, it is an excellent means of detecting transmission errors in digital data communications. CRC is popular and is used in many systems, like the Internet, Ethernet, Public Switched Data Networks, Token-ring Networks, and amateur packet radio. The mathematics and the electronics are very simple and the circuits can be easily constructed. By inferring from the given example, circuits for any divisor pattern can be produced.

We also found that, with a slight modification to the CRC philosophy, a data encryption method could be realized that would effectively privatize information between networks and, most importantly, would still possess all the error detection capabilities, too.

What I did not elaborate on is how the association between modulo-2 math and the digital circuits works and what pattern code words are best. This, unfortunately, would require a whole course on the theory of error control codes, with all of the attendant linear and abstract algebra. It would be difficult to condense into just a few pages.

Fortunately, there are many books on the subject for those who want a deeper understanding. Internet searches for CRC will also provide much information on this topic. What I have hopefully done is given enough guidance for you to experiment with Cyclic Redundancy Check for yourself. **NV**

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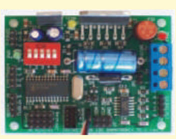

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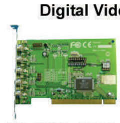

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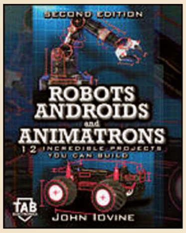

In *Robots, Androids, and Animatrons,* Second Edition, you get everything you need to create 12 exciting robotic projects using off-the-shelf products and workshop-built devices, including a complete parts list. Also ideal for anyone interested in electronic and motion control, this cult classic gives you the building blocks you need to go practically anywhere in robotics. **$19.95**

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A major revision of the bestselling "bible" of amateur robotics building — packed with the latest in servo motor technology, microcontrolled robots, remote control, Lego Mindstorms Kits, and other commercial kits. **$24.95**

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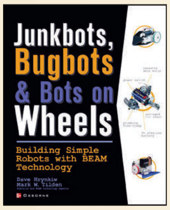
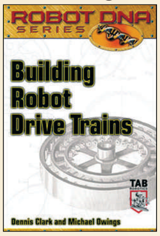
JunkBots, Bugbots, and Bots on Wheels: Building Simple Robots With BEAM Technology
by David Hrynkiw / Mark Tilden



Ever wonder what to do with those discarded items in your junk drawer? Now, you can use electronic parts from old Walkmans, spare remote controls, and even paper clips to build your very own autonomous robots and gizmos. Get step-by-step instructions from the Junkbot masters for creating simple and fun self-guiding robots safely and easily using common and not-so-common objects from around the house. Using BEAM technology, ordinary tools, salvaged electronic bits, and the occasional dead toy, construct a solar-powered obstacle-avoiding device, a mini-sumo-wrestling robot, a motorized walking robot bug, and more. Grab your screwdriver and join the robot-building revolution! **$24.99**

Building Robot Drive Trains
by Dennis Clark / Michael Owings

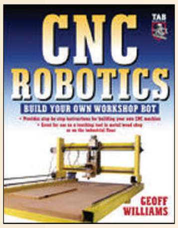


This essential title is just what robotics hobbyists need to build an effective drive train using inexpensive, off-the-shelf parts. Leaving heavy-duty "tech speak" behind, the authors focus on the actual concepts and applications necessary to build — and understand — these critical force-conveying systems. **$24.95**

Everything you need to build your own robot drive train:

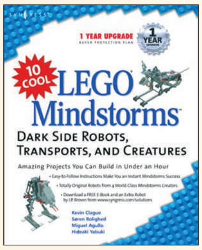
- The Basics of Robot Locomotion
- Motor Types: An Overview
- Using DC Motors
- Using RC Servo Motors
- Using Stepper Motors
- Motor Mounting
- Motor Control
- Electronics Interfacing
- Wheels and Treads
- Locomotion for Multipods
- Glossary of Terms, Tables, and Formulas

CNC Robotics
by Geoff Williams



Written by an accomplished workshop bot designer/builder, *CNC Robotics* gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80% of the price of an off-the-shelf bot — and can be customized to suit your purposes exactly because you designed it. **$34.95**

10 Cool LEGO Mindstorms: Dark Side Robots, Transports, and Creatures
by Kevin Clague / Søren Rolighed / Miguel Agullo / Hideaki Yabuki



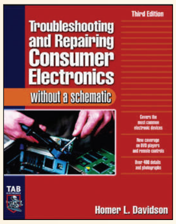
Okay, you bought the kit for yourself or one of your kids. You used the instructions in the box to build a robot or two. Now what? You may not be ready to design and build your own robots, but you don't want to build the same robot over again. This book is the perfect aide for building additional projects from the same kit, then improving and designing your own. Ten cool projects — one hour each — perfect! **$24.95**

Mobile Robots: Inspiration to Implementation, Second Edition
by Joseph L. Jones / Anita M. Flynn / Bruce A. Seiger

Revised and updated, the second edition includes several new chapters with projects and applications. Robotics has made quantum leaps since the first publication of *Mobile Robots: Inspiration to Implementation.* With the publication of the second edition, the authors keep pace with the ever-growing and rapidly expanding field of robotics. The new edition reflects technological developments and includes programs and activities for robot enthusiasts. Using photographs, illustrations, and informative text, *Mobile Robots* guides the reader through the step-by-step process of constructing two different and inexpensive — yet fully functional — robots. **$34.00**

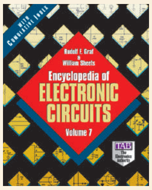
Electronics

Troubleshooting & Repairing Consumer Electronics Without a Schematic
by Homer Davidson



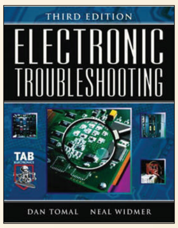
In this book, Homer Davidson gives you hands-on, illustrated guidance on how to troubleshoot and repair a wide range of electronic products — when you can't get your hands on the schematic diagrams. He shows you how to diagnose and solve circuit and mechanical problems in car stereos, cassette players, CD players, VCRs, TVs and TV/VCR combos, DVD players, power supplies, remote controls, and more. **$34.95**

Encyclopedia of Electronic Circuits, Volume Seven
by Rudy Graf



Designed for quick reference and on-the-job use, the *Encyclopedia of Electronic Circuits*, Volume Seven, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. This collection includes the latest designs from industry giants, such as Advanced Micro Devices, Motorola, Teledyne, GE, and others, as well as your favorite publications, including *Nuts & Volts*! **$39.95**

Electronic Troubleshooting
by Daniel Tomal / Neal Widmer

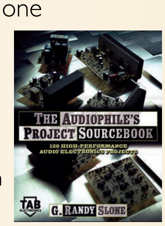


If you work with electronics — either through your profession or your pastime — here's one resource you need handy at all times: the updated Third Edition of McGraw-Hill's *Electronic Troubleshooting*. Revamped to include the latest electrical and electronic devices and problem-solving methods, this information-packed volume provides a fundamental understanding of electronic troubleshooting theory. **$49.95**

Build Your Own Printed Circuit Board
by Al Williams

With *Build Your Own Printed Circuit Board*, you can eliminate or reduce your company's reliance on outsourcing to board houses and cut costs significantly. Perfect for advanced electronics hobbyists as well, this easy-to-follow guide is by far the most up-to-date source on making PCBs. Complete in itself, the handbook even gives you PCB CAD software — on CD – ready to run on either Windows or Linux. (Some PCB software costs from $10,000.00 to $15,000.00!) **$27.95**

The Audiophile's Project Sourcebook: 120 High-Performance Audio Electronics Projects
by G. Randy Slone



The Audiophile's Project Sourcebook is devoid of the hype, superstition, myths, and expensive fanaticism often associated with high-end audio systems. It provides straightforward help in building and understanding top quality audio electronic projects that are based on solid science and produce fantastic sound! **$29.95**

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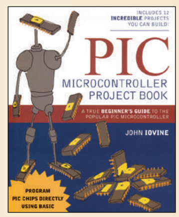
Programming & Customizing PICmicro Microcontrollers, Second Edition
by Myke Predko

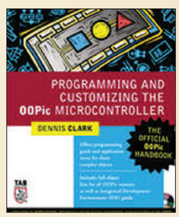
This book is a fully updated and revised compendium of PIC programming information. Comprehensive coverage of the PICmicro's hardware architecture and software schemes complement the host of experiments and projects, making this a true "learn as you go" tutorial. **$49.95**

PIC Microcontroller Project Book
by John Iovine



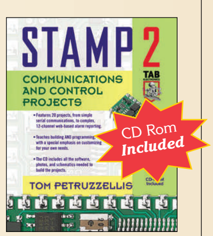
This project-oriented guide gives you 12 complete projects, including: using transistors to control DC and AC motors, DTMF phone number loggers, distinct ring detector and routers, home automation using X-10 communications, digital oscilloscopes, simulations of fuzzy logic and neural networks ... and many other applications. **$29.95**

Programming and Customizing the OOPic Microcontroller
by Dennis Clark



If you're a robotics professional or hobbyist, here's the one book you'll need to keep your work on the leading edge — *Programming and Customizing the OOPic Microcontroller*. This is the official OOPic Handbook, fully endorsed by Savage Innovations, the world's only manufacturer of OOPic microcontrollers. As the first book of its kind, this volume is destined to become the standard against which all other OOPic books will be judged. **$39.95**

STAMP 2: Communications and Control Projects
by Thomas Petruzzellis



With the help of detailed schematics, informative photos, and an insightful CD-ROM, *STAMP 2: Communications and Control Projects* leads you step-by-step through 24 communications-specific projects. As a result, you'll gain a firm understanding of Stamp 2 and its programming methodologies — as well as the ability to customize it for your own needs and operating system. **$29.95**

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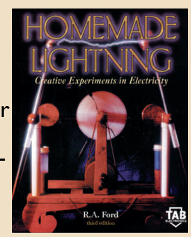
High Voltage

Homemade Lightning: Creative Experiments in Electricity
by R. A. Ford



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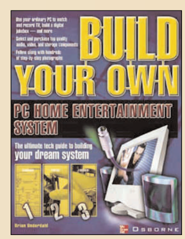

Learn to use PC DVD drives, DVD recorders, and massive hard drives to create a home entertainment system that's comparable to what you'd enjoy from expensive, individual components. Who needs the movies? Now, you can achieve stunning audio and top quality video results through your PC. This book shows you how to build your own home entertainment center using an ordinary PC. Watch and record TV shows and movies, put your entire CD collection on your hard drive, and listen to radio stations from around the world. **$24.99**

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Understanding, Designing, and Constructing Robots and Robotic Systems

Personal Robotics

Universal Robotics Controller

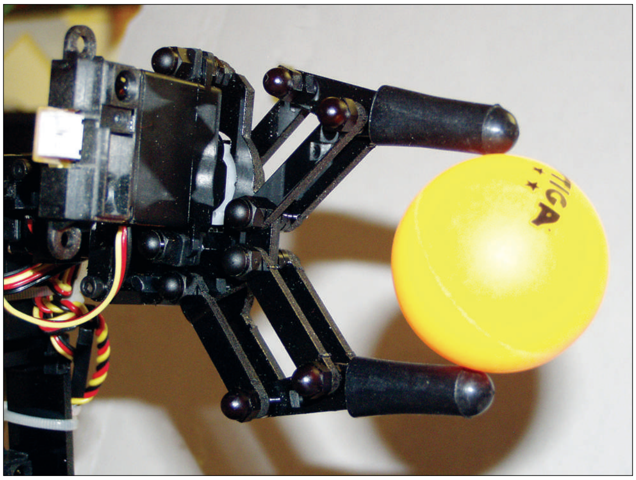
Very often, in our quest for functionality, we stray away from our processor of choice when we need a feature that just isn't found in our magic bag of tricks. Often times, we are forced to look in directions we wouldn't normally consider.

Consider the desktop PC — most likely interfaced to a 20 GB or larger hard drive, possibly with more than 256 MB of RAM, and probably running at better than a 1 GHz bus speed. Try generating accurate PWM on the parallel port, however, and you are in for a challenge. The desktop PC just isn't made for that.

In this article, I will lay out some groundwork for a "universal robotics controller" that, for convenience, will initially be interfaced to a personal computer via RS232 or a USB to RS232 converter, but could just as easily be adapted to other microcomputers and microcontrollers via RS232, RS422, RS485, SPI, or even CANbus.

To keep things fun, I have chosen to interface to LynxMotion's L6 robotic arm. The L6 arm has six R/C servos and presents quite a challenge from a dynamics point of view. Instead of using the IsoPod™, I decided to try my hand at the ServoPod™, the IsoPod's big brother. The ServoPod is essentially identical, except that it has more storage and more analog inputs. Also, since it was specifically designed for R/C servos, it is a little easier to work with, as well. To accomplish this, we need a few key elements: a command interpreter, a kinematics engine, and a motion processor.

The command interpreter is our interface to the outside world. The kinematics engine essentially uses trigonometry to "untangle" the arm into an easily manageable system. Finally, we have a motion processor that will drive our R/C servos. Because of the modularity of IsoMax, we easily re-write any of these elements to accommodate different hardware. To work off the CANbus, for instance, we simply redirect the command interpreter to look at the CAN module for input, rather than the serial port. Similarly, if we wanted to run six quadrature encoded motors instead of R/C servos, we would simply re-write the motion processor to accommodate six PID loops and accept quadrature feedback from the timer modules.



In order to accomplish Step 1, we have to "lift the hood" on IsoMax. Be prepared, because this is where things get a little wired (cool for weird). IsoMax, a superset of FORTH, is like a programming language construction set. With it, you build new words by stringing together previously defined words. These words themselves can further be strung together into even more words. In this way, what you are doing is writing your own language and, the deeper you nest these words, the higher the level of the language you are writing, since the words get more specific to the task at hand. The converse of this is true regarding the previously defined words. The deeper you go into their own definitions, the closer you get to the compiler and command interpreter. This deep, dark place is where we will draw our secrets from in order to build our own command interpreter. We will tap into the power of EVALUATE (see sidebar).

EVALUATE looks at a string at a given address, of a given length, and acts upon it as though you had typed it in. In this example, we are looking at the terminal input buffer, but we can re-write it to look at any input stream.

The implications of this are far-reaching. For instance, you can actually build software that writes software by combing previously defined words into strings and executing them on their own. In the context we care about, this means that you can accept a stream of data from any source and act on it. Because of this unique architecture, we can simply tell the command interpreter to look at something and

do what it says. All the groundwork for telling the processor to do something has already been laid out and it is simply up to us to inject our commands that we want operated on.

To do this in another language, you would have to build up a deep IF/THEN or CASE structure to filter through the received data, look for valid commands, build up a final condition for the bit of code you want executed, and then execute that bit. By using EVALUATE, we can choose our input stream and build our own command interpreter, above IsoMax's command interpreter.

Never one to leave things simple, I like to build an extensible architecture. If I am going to have a bunch of identical pieces of code running about on separate modules or virtual modules on the same piece of hardware, it is necessary to have some sort of addressing scheme. I prefer to use ASCII characters in the range of 0x80 to 0xFF, with ASCII 0x80 as a global address and all address above that as unique addresses.

This isn't to say that you must have a single address for one piece of hardware; it just means you can have multiple occurrences of identical hardware or software all running on the same bus. This works particularly well on multi-drop serial networks.

So now, instead of using the typical method of filtering through a nest of IF/THEN statements to determine what command we want to execute, we use some simple state machine architecture to filter the address bytes of our serial data and some more state machine stuff to turn the data into something that EVALUATE can understand. Of course, there is always more "cool" to explore. In this case, it is the ability to "turn off" most of IsoMax. By closing the dictionary of previously defined words at a certain point in memory, only the words defined after that point will be available through our own command interpreter. This will keep us from accidentally "bumping into" IsoMax words that could be dangerous. Here, we can even redefine words present in the language, thus giving us a fusion of IsoMax and whatever else we are defining (see Figure 1).

EVALUATE

```
: EVALUATE ( addr n -- )
    TIB @ >R  >IN @ >R  #TIB @ >R (TIB is the terminal input buffer
    2DUP + 0 SWAP C!        (append a null terminator, req'd by INTERPRET
    #TIB !  TIB !             (tell interpret how big and where it will work
    0 >IN !                   (reset the input stream
    INTERPRET
    R> #TIB !  R> >IN !  R> TIB ! ; (leave things how we found them
```

You can tell how deep in the language we are by looking at the definition of EVALUATE, which relies on INTERPRET as the basis of its functionality. INTERPRET literally does just this; it interprets the input string. If you do a listing of WORDS, you will see that INTERPRET is defined very early in our stream of word definitions.

Now that we have the command interpreter out of the way, we can concentrate on the kinematics of our code. Since the Lynxmotion arm is so robustly constructed, it is feasible to do this while still expecting reasonable results. I had feared that I would have to add encoding to the L6 arm to get accurate positional information from the arm because of the non-linearity of the servos. As it turns out, though, I didn't have to turn towards the ServoPod's quadrature readers or analog channels. Instead, I ran the servos' open loop and expected them to reach their commanded positions with reasonable accuracy.

There are actually two different directions we can approach the issue of kinematics from.

First, we can take all of the commanded joint positions and calculate the position of the tip; we can also take the commanded position for the tip and calculate the joint angles required to achieve that position. These methods are called forward and inverse kinematics, respectively. Consult Figure 2 to get a better sense of what is going on.

Since the entire arm moves perpendicular to the ground, all of the joints lie on the same plane. This plane rotates with the base's servo, so the angle of the arm is the angle of the base. The next two coordinates — the radius and the height — can be calculated from the cosines and sines of the joints (SHOULDER, ELBOW, and WRIST), multiplied by the lengths (HUMERUS, ULNA, and HAND), with BASE as an offset.

The height of the ELBOW is simply:

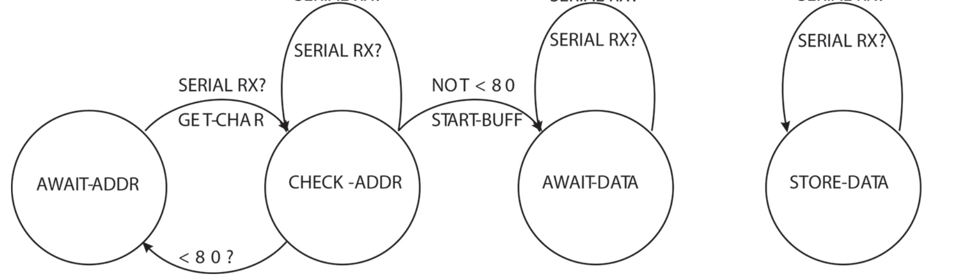
```
SIN(SHOULDER) * HUMERUS + BASE
```

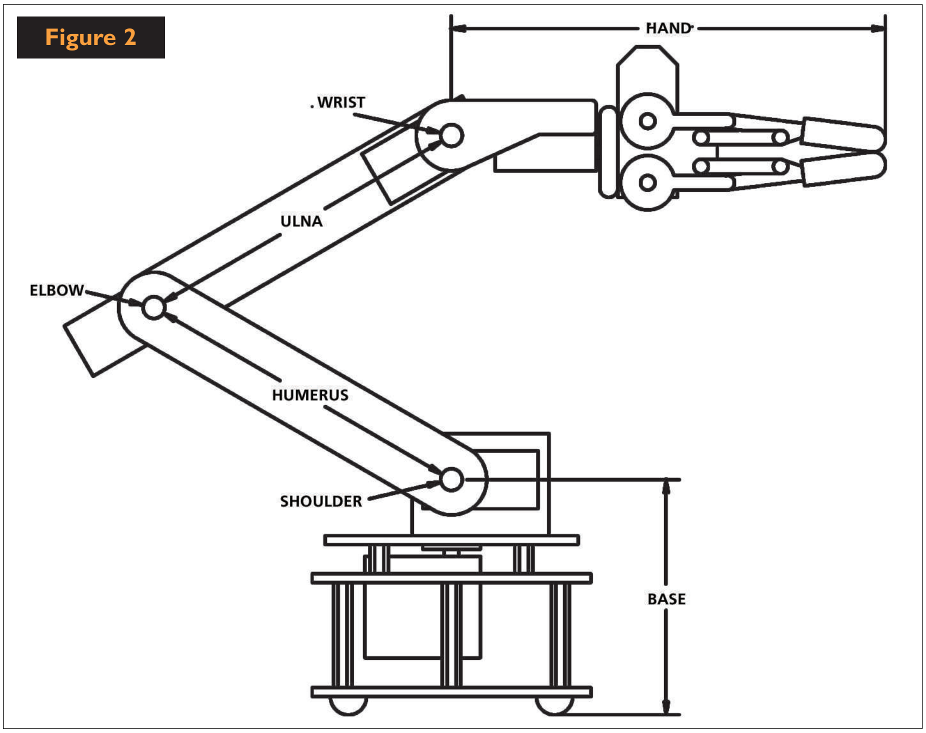
The radius is simply:

```
COS(SHOULDER) * HUMERUS
```

A similar process finds the positions of the WRIST, with only some minor additions to the formula.

Figure 1





The height is:

```
SIN(SHOULDER + ELBOW ) *
   ULNA + ELBOW + BASE
```

The radius is:

```
COS(SHOULDER + ELBOW ) *
   ULNA + ELBOW
```

To get the final position of the Tip, we take it a bit further.

The height is expressed as:

```
SIN(SHOULDER + ELBOW + WRIST) *
   HAND + ELBOW + WRIST + BASE
```

Finally, the radius of the tip is:

```
COS(SHOULDER + ELBOW + WRIST) *
   HAND + ELBOW + WRIST
```

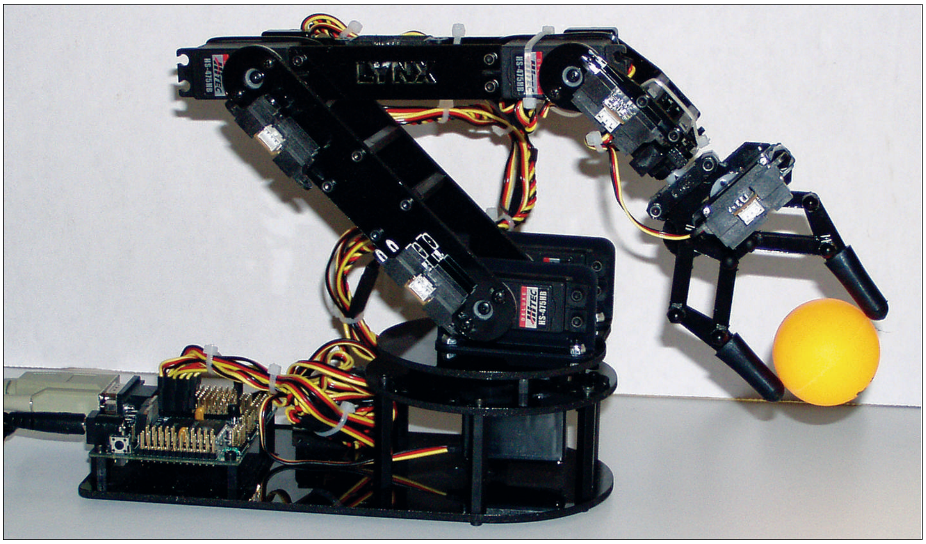
If different co-ordinate spaces are more useful to you, feel free to jump over to X-Y-Z or spherical, if you so choose.

The next case, working out the joint angles in response to a Cartesian input, is a little trickier. I know I am bleary-eyed from reading that last bit of trig, so, rather than lose my audience in a bunch of math, I have encoded this information into a cute little Microsoft Excel spreadsheet, which is available online at **www.nutsvolts.com**

Not happy with a simple six-axis robotic arm, I decided to make things interesting. I decided to litter the L6 arm with a bevy of Sharp GP2D120 analog distance sensors. These will allow the arm to have a rudimentary sense of its environment and, hopefully, keep us from knocking into things. Some of these sensors will be mounted to additional R/C servos, allowing me to independently scan for objects on the platform around the arm. Thanks to the floating point in the ServoPod, the single line of code converts the output of the GP2D120 to inches.

```
: FDIST S>F FNEGATE 1.00623082E03
F/ FEXP 2.66564399E01 F*
   2.224960E0 F+ ;
Inches=2.224960+26.6564399*
   e^(-(A/D counts)/1006.23082)
```

We can also adapt the forward kinematics to calculate the locations of the objects that the Sharp sensors are seeing. If you treat the angle of the sensor to the arm as a joint angle and the distance the sensor reads as the length of a joint, then you can get the coordinates of the object the sensor is reading. The distance the sensor reads is now the next segment length! In this way, if we see something that we calculate at anything above 0, we know it is a "thing". By scanning the arm around, we can effectively map the "thing" and determine whether it is something our gripper can accommodate (see Figure 3).



The last piece of the puzzle is fairly straightforward. Driving R/C servos is pretty much routine for the personal roboticist. A command pulse of 1.0 to 2.0 ms every 50th of a second controls the position of the output shaft. Luckily for us, the ServoPod does this with hardware registers.

Be warned that the command pulse length varies somewhat from

manufacturer to manufacturer and from model to model. It is even possible to damage a servo by running it into its end stops. (Not that I speak from experience, mind you.) What this means in the long run is that we should calibrate each servo's position, compared to its command pulse. This will allow us to command the output in units we are accustomed to and have the servo respond predictably by building a table in code which contains the minimum and maximum servo input range and the corresponding values we write to the command registers to achieve them.

We can achieve ultimate control by building a motion processor. This processor will run at a periodic rate, typically the update rate of the R/C servos, since any faster wouldn't do us much good. We will provide this processor with the desired acceleration, velocity, and position of our servos. With every cycle through the motion processor, the processor will increment the servo's position by a specific amount that we can call a velocity. In addition, we can increment this velocity, starting at 0 and continuing to some maximum, by an acceleration.

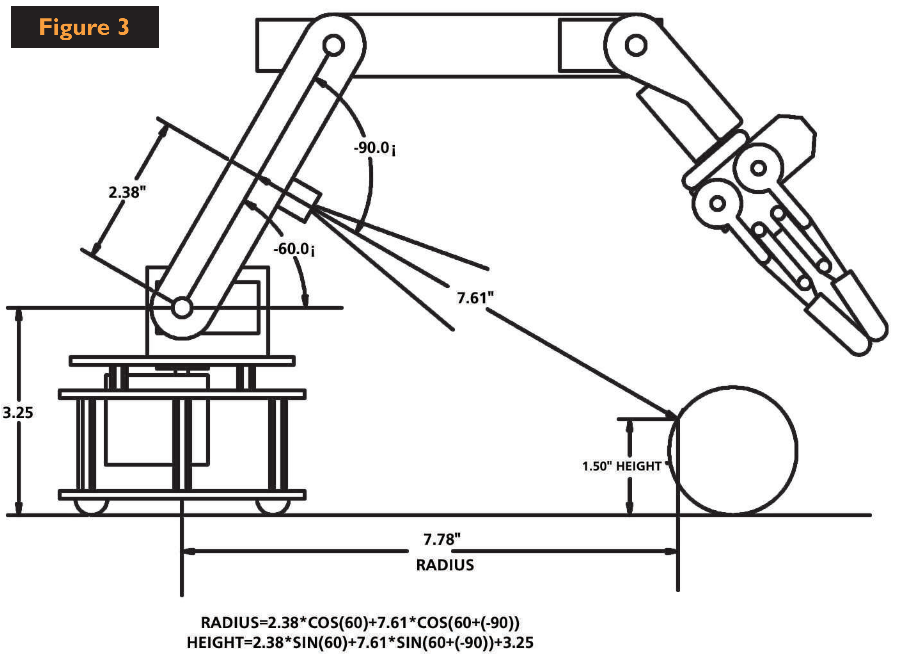
When we get to the point in our program when it is time to slow down, we decrement our velocity by our acceleration amount until we reach a speed of zero, at which point we will be at our desired position. In this way, we can achieve smooth, controlled motion.

So, to tally up our hardware, we have a LynxMotion L6 arm, which has six R/C servos (two R/C servos with GP2D120s mounted to them) and five more GP2D120 distance sensors mounted to the arm. This leaves us another nine analog inputs, which I will eventually use six of to add current sensing to the arm's servos. It also leaves us with 14 more outputs that can control R/C servos or even quadrature encoded motors.

In terms of software, we have built our own servo control language to which we can add other functionality as the need arises, like sensing current, controlling other devices, or orchestrating communications through other channels. It is even possible to use the IsoPod purely as a numerical co-processor, handling floating-point operations for more taxed elements of your system.

Hopefully, I have sparked your imagination and sent your mind reeling, looking for other applications. Please visit **ww.nutsvolts.com** for spreadsheets and source code pertaining to this article. **NV**

Figure 3



The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Troubleshooting Circuits

Much of a design engineer's time is spent making things that aren't working work. Often times, this can be a real challenge, especially if the design steps (circuit design, board layout, assembly, etc.) are performed by different people. The engineer must determine not only the problem with the product, but also which design step is faulty and how to correct it. This month, we'll look at some approaches that can help in such situations.

Repair

Engineers are generally not called in for simple repairs — it's too expensive. However, they may be called in to determine the cause of failures. For example, the pass transistor in the power-supply fails too often; this is really a circuit analysis problem and will not be discussed. After all, the problem with the circuit has been identified. Rather, we will discuss how to find and identify circuit problems.

Engineers will often be called to locate a failure that suddenly appears for no apparent reason with a product. It is very important to know beforehand that there is, indeed, a reason. Something has changed. Regardless of what the manager or technician has said, something is different in the new product. This is obvious; if nothing had changed, the product would still work.

Sometimes, but not very often, the failure has a fairly obvious cause. I say not often because something that is easy to fix often would have been found by a technician — engineers get the juicy problems.

In most instances, the best approach is to put a working old product and a failing new product side by side and compare any differences.

First, do a detailed visual examination. Is the PCB (Printed Circuit Board) the same revision? If there is even a minor difference in parts layout, you can be sure the revisions are different. Look closely. Are all of the parts identical? Do the capacitors and resistors have the same values? Sometimes, someone grabs a wrong reel and 10K ohm resistors are where 1K resistors should be. Are the tolerance values the same? Are the ICs (integrated circuits) identical and from the same manufacturer? Most often, a 74LSxx and a 74ALSxx are compatible, but not always. Even worse, different manufacturers have different manufacturing processes, which results in the "same" chips being different.

I think it's important to really note this point. The "same" chips from different manufacturers can be very different. Take the 74LS123 chip as an example; this is a timer chip and uses an external resistor and capacitor (RC) for timing. The table below shows the nominal timing for a 10K resistor and 100 pF capacitor.

Signetics	**500 nS**
Texas Instruments	**600 nS**
SGS (Thompson)	**530 nS**
Motorola	**550 nS**

You can see that there is up to a 20% difference in pulse widths. If a 74123 is used for a 74LS123, the difference can be as much as 100%. I chose this old part to illustrate a point; if a basic, simple circuit like the 74LS123 is so different, what will the difference be with different manufacturing processes (74HCxx, 74ALSxx, 74Hxx, etc.)? What does complexity add to the difference? That's simple — the more complicated the chip, the greater the likelihood of difference.

Even the same chip from the same manufacturer can be different. In particular, "die shrink" parts (parts reduced in size to use less silicon) can be subtly different.

Does your new product use a "B" version of the microprocessor (µP) while the old one has an "A" version? Of course, if there is a programmed part in your product, you must check if the programming is the same. This last question is not always easy to verify, but should be.

If there are no physical differences between the old and new versions, you will have to examine the electrical differences.

The best way to do this is with a side-by-side comparison. It's helpful to reduce the size of the problem, if you can; you can use the same power supply for both boards. Remove or disable extraneous circuits; if this makes a difference, you've found an important clue. Once you've located an electrical difference, finding the problem is usually fairly straightforward. Be patient, thorough, logical, and think about what you are doing.

Don't forget to take notes; there's nothing worse than wondering if something you saw yesterday is different today. Remember, there must be an electrical difference or there wouldn't be a problem.

Re-design

If you don't have an old product to compare with the problem unit, then you have to treat it as a re-design problem. This approach is a little more

general and less mechanical than comparing two units. Normally, you will have had some contact with the re-design because re-designs are done by engineers. However, with overseas contractors, high turnover rates, force reductions, and everything else, it's becoming more common to be called in cold.

When troubleshooting a re-design, you do have the knowledge that a similar product did, indeed, work at some time in the past. This means that it's unlikely to find a fundamental error in the design. Rather, you are expecting to find a more subtle error. You are looking for an incompatibility, rather than an outright failure.

First, define precisely what the problem actually is. It's surprising how often this is overlooked. What defines a failure and what defines proper operation? These specifications should be available. If not, you may never be able to fix the problem.

For example, a friend was once tasked to reduce the noise in a specialized counter. The last three digits weren't stable. The first day, he found some power supply noise that could be filtered out and, by doing so, he was able to improve matters. Only the last two digits were unstable. After two more days, he got down to only one unstable digit.

Finally, at the weekly meeting, he had to admit that he was having real problems getting the last digit stable without significant changes to the circuit. His boss answered, "Only the last digit is unstable? Gee. That's better than it's ever worked." It turned out that the last two digits were expected to be unstable. He had spent four additional frustrating days trying to make something "work" when it was already working to specifications.

Once you define the problem, you can usually find it fairly quickly. However, finding the problem and finding the cause of the problem can sometimes be two different things. Nevertheless, this generally targets the problem to a specific area, which is important.

This tells you where to concentrate your efforts. A failure in one circuit rarely causes a failure in an apparently unrelated circuit — rarely, not never. The first thing I do is carefully check the power supply. It is amazing how many bizarre effects can come from a problem there. Look for noise, spikes, etc. A high frequency oscilloscope is required. Sometimes, a spectrum analyzer is useful here. Check at the power-supply source, at the suspected circuit, and at individual chips of that circuit. (I had one µP that actually executed the wrong instructions when the power supply was too low.)

RF (radio-frequency) noise on the power supply line is sometimes difficult to see, but can wreak havoc with both analog and digital circuits. Analog IC front-ends rectify RF and can cause drift, offset, oscillation, distortion, and lots of other strange effects. Digital circuits can get triggered, reset, or simply latched-up.

If the power supply is okay, then you have to actually think. What could cause the problem you are seeing? (Sometimes, it's useful to make a list.) Next, devise a way to test for this possibility. Run the test and see what happens. Again, it's useful to document what you do; this saves you time and confusion if the cause of the problem is hard to find.

Make a Test Circuit

Sometimes, you can't easily do a test on the circuit in question. Perhaps you want to cut a lot of traces or need access to a point that is physically difficult to get to. In this case, it's sometimes possible to make a test circuit. This is almost always useful, but, because of the time and effort involved, it's not always practical.

If the test circuit fails in the same way as the problem circuit, then you have a much easier circuit to work with. You've eliminated extraneous parts of the system and have narrowed the problem down to a unit that you can control better. On the other hand, if the test circuit works properly, you now have something to compare the faulty circuit with. Clearly, this makes things easier, too.

Add Sockets

Often, you'll want to measure current in to or out of a chip, add noise filters, or do other things that are not easily accomplished with the IC on the board. The answer is to put in an IC socket. This makes pin isolation easy. Just bend it outward slightly, so that it doesn't go into the socket. The ability to use "component carriers" or "DIP headers" with sockets is an even better option. These allow you to physically connect any circuit to a socket. I've seen some plug-in test circuits on headers that were very complicated.

If your product doesn't use DIP (Dual In-line) footprints (which is increasingly the case) you may have to improvise. Sometimes, it's possible to buy converters. Often, you can make something. If your product uses a 200 pin IC with 0.5 mm lead pitch ... never mind.

New Design Troubleshooting

The vast majority of engineering and hobbyist troubleshooting is done with new designs. You are trying to get something to work for the first time. The problem could be anywhere. Perhaps there is a wiring error. Perhaps the PCB is wrong. Perhaps there is an assembly error. Perhaps the design is faulty. How do you determine the problem?

The most important problem to solve is the design question. Are you sure the design *can* work? Very often, there are points that are not addressed in the design that are important. Sometimes, components don't work as expected. Other times, concepts are misunderstood. Often, wishful thinking is at work. The classic example of this is the, "motor that drives the generator that drives the motor," perpetual motion machine. It simply can't work. The only way to solve this problem is with education and experience.

Analog and digital simulation can be helpful here. If it doesn't work on the simulator, it's not going to work in hardware. (Note — a working simulation in no way guarantees working hardware.) Another person could examine your design and tell you if it can work. Sometimes, you just have to try it yourself. There is no shame in learning by trial and error.

Breaking the Loop

One of the most difficult things to troubleshoot is a closed loop system. The problem could be anywhere. You can't open the loop because feedback is required for operation. The best tactic is to stop and think. Brainwork is hard, but it's the most likely approach to work. Let's look at an example. A client asked me to find the problem in

a high-voltage generator; the output was not stable. The unit measured the output voltage and fed it back as an error signal into an op-amp regulator circuit. It was easy to find the noise on the output of the op-amp, but was the op-amp causing the noise or was it just amplifying it? What's more, the noise was so great that it was seen on the power supply rail. So, was the power supply noisy or was the circuit noisy?

The last question was fairly easy to determine. I cut the power supply trace to the op-amp and inserted a 100 ohm resistor. Then, I put parallel 100 µF and 0.1 µF capacitors from the op-amp power pin to ground. This isolated the op-amp from the rest of the power supply. The capacitors filtered out noise. The result was clean power to the op-amp, but the noise was still there.

I spent most of the day chasing the noise around the op-amp circuit. I filtered here. I filtered there. I filtered the reference. Nothing made a difference. Finally, I sat down and just thought — where could the noise be coming from? The op-amp circuit was simple. It obviously wasn't coming from where I was testing. It had to be coming from somewhere else. The only other place was the grounded pin of the op-amp, but it was grounded! What kind of signal could come from a ground? I used an ohmmeter to verify that the pin was, indeed, grounded.

Once this was established, I hooked up the oscilloscope with the ground lead to the main power supply ground and probed the "grounded" op-amp pin. Surprise! There was noise at the op-amp that wasn't at the power supply. This was the source of the noise. I took a piece of heavy gauge wire and connected it directly from the power supply ground to the op-amp ground pin. The noise went away and the circuit worked perfectly. This incident illustrates several important points. If you aren't getting anywhere with your approach, then your approach isn't working and it's time to try something different. Taking a break and re-thinking the problem can help with this. Noise can enter the circuit from *any* pin — even the ones you don't think of as possible. Ground noise is something you must always be aware of. It plagues analog and digital circuits. It comes from improper PCB layout. (Inexpensive PCB auto-routers are notorious for this.) Finally, it shows that you can't believe what your client says. He had initially denied that there were any changes. When shown that the grounding was faulty, he was forced to admit that, "just a few," traces were re-routed, "but the circuit wasn't changed."

Intermittent Problems

By far, the most likely cause for an

intermittent failure is a bad connection. Cables, sockets, solder joints, and broken traces are common problems. Tapping components, flexing the board, bending cables, and re-heating solder joints are ways to find problems like these. With analog circuits, if it's not a bad connection, it's probably heat-related. There are a few other mechanisms for analog circuits which occasionally fail. Look at the schematic and find the most likely parts, then heat them with a heat gun and cool them with a cooling spray to find the culprit. Sometimes, multiple parts have to be heated/cooled for the problem to be seen. This means you may need a refrigerator or heat chamber for testing.

With digital circuits, intermittents are usually caused by timing errors (when a bad connection is not at fault). Sometimes, heating and cooling will make the problem better or worse, but the fundamental problem is *not* caused by temperature. It's an error in the timing. Heating and cooling only change the timing slightly. These problems can be difficult to find because timing is a relative thing. A clock pulse to a counter may look fine, but, if it occurs too soon after a reset, there may be problems. You need a good timing diagram of the circuit. Please don't say you don't have one. The timing diagram for a digital circuit is just as necessary as a schematic. (Proper attention to set-up and hold times is absolutely critical for reliable circuit operation.) If a timing diagram isn't available, you will probably have to make one. Yes, this takes a lot of time, but if a proper diagram was available during the design stage, then this problem would probably have been identified and eliminated at that time. (Also — let's be practical — you'll probably need the diagram sometime in the future, anyway.) Usually, you will actually save time by stopping and making the timing diagram for two reasons. The first is that, by generating the diagram, you are required to analyze and understand the circuit. Second, it's a powerful troubleshooting tool. The exception to intermittent digital circuits occurs when software is involved. Erratic software has an entirely different cause. Troubleshooting software is something that books are written about — we won't discuss it further, now.

Phantom Power

How many times have you forgotten to apply power to a circuit and wondered why it wasn't working? On several occasions, I have seen CMOS ICs apparently working without power. They even appear to work well! Here's how this happens. There are clamping diodes on every input pin to reduce latch-up and to protect against over- or under- voltages. These diodes steer current to the power rails. If the input is greater than the positive supply, the current is passed to the power pin. If the voltage is less than ground, it is passed to ground. An IC that doesn't have the power pin connected will have the power pin driven internally by any positive signal on the input pins via the protection diodes. With a typical capacitor across the power pin to ground, the power pin can actually get charged up to a diode drop below the input signal. With the low current requirements, that may be enough to make the IC look like it's operating properly, but it isn't. The voltage is reduced by at least a diode drop (0.7 V) at the output. So, if this signal is used to drive the next layer of logic, that output will be an additional diode drop lower. You can see that, after a few levels of logic, there is no voltage left to drive anything. In addition, the operational speed is greatly reduced, although this may not be apparent at first glance. In other words, while it may initially appear to be a cute trick to power circuits, it really isn't a practical design approach. It is a strange thing to troubleshoot, and it's quite common to see this on new circuit designs. CMOS 4000 series and 74Cxx series ICs exhibit this effect. I don't think any other logic families do. This may carry over to other low-power CMOS devices, like microprocessors and other specialized ICs. They all have clamping diodes, as well.

Conclusion

Troubleshooting is different depending on whether the product is new or in need of repair or re-designing. The best tool is between your ears. If you understand the product well, you will be able to troubleshoot it well. Experience is also helpful. Hopefully, some of these examples and approaches will be useful. NV

Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Stamp Applications

Measure High, Measure Low

The unappreciated lookup table swings into action this month!

I'm pretty sure I've made this confession before, but if I haven't, here goes: I'm a bit of nut when it comes to temperature. Let's just say that I have an exceptional temperature curiosity. I have thermometers of one sort or another spread from one end of my home to the other and I seem to be checking them constantly. I even found a useful little atomic travel clock with a thermometer built in; I can keep track of the exact time when I travel and monitor the environment at the same time — I like that.

In science and industry, one of the most popular methods of measuring temperature is with a thermocouple. They're inexpensive and fairly accurate. They're easy to use, but the process of using them properly is not necessarily very simple. Let's back up a bit ... a thermocouple is constructed by joining two dissimilar metal wires at one end (see Figure 1). A voltage will be developed between the joined and open end that is proportional to the temperature difference between the two ends. This is called the Seebeck voltage, named after Thomas Seebeck, who discovered the affect in 1821.

The trick is that Seebeck voltage is very small — on the order of fractional to low millivolts — so we just can't pull out our trusty DMM and measure it. Another point for consideration is establishing a reference at what is called the "cold junction" (the point where we measure the Seebeck voltage). This connection is called the cold junction because, prior to electronic compensation, this connection point was placed in an ice bath to keep it at (or very near) 0°C. If you look at a standard thermocouple table, you'll see that the reference junction is specified at 0° C.

Lucky for us, technology is on our side. Dallas Semiconductor makes a neat little chip called the DS2760, which was actually designed for monitoring Lithium-ion batteries, but works very nicely as a thermocouple interface. To the best of my knowledge, the use of the DS2760 as a thermocouple interface was originally presented by Dan Awtry of Dallas Semiconductor. What we're going to do this month is create a program for the BS2pe (or BS2p) that will talk to the DS2760 and display the thermocouple temperature in Celsius and Fahrenheit.

Temperature on a Wire

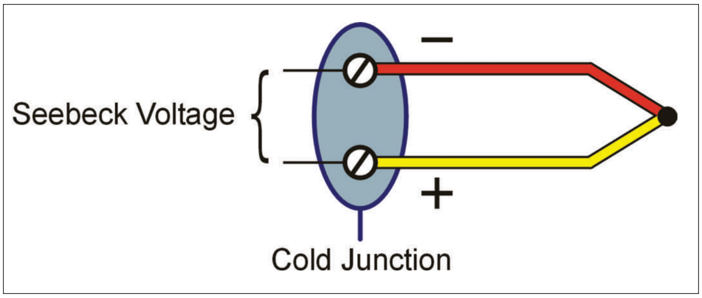
As you can see in Figure 2, the DS2760 is a one-chip solution for thermocouple interfacing. The BS2p/BS2pe makes talking to a 1-Wire device a snap; the rest is just assembling the code. Here's the plan:

- Measure the cold junction temperature (this comes from inside the DS2760).
- Measure the Seebeck voltage.
- Find the thermocouple voltage that corresponds to the cold junction temperature.
- Adjust the Seebeck voltage based on the cold junction temperature.
- Look up the compensated temperature and display on the LCD.

Alright ... you know the drill: We've planned our work, now let's work our plan.

Let's start at the top and make sure that we actually have the DS2760 connected. Note that this program is designed for just one sensor — it can be modified for multiple units, but that's beyond the scope of what we're going to do here. (You could, for example, include tables for various thermocouple types and select the type — you can download an example from Parallax.) After checking to make sure that we're connected to a BS2p or BS2pe

Figure 1. Thermocouple connections.



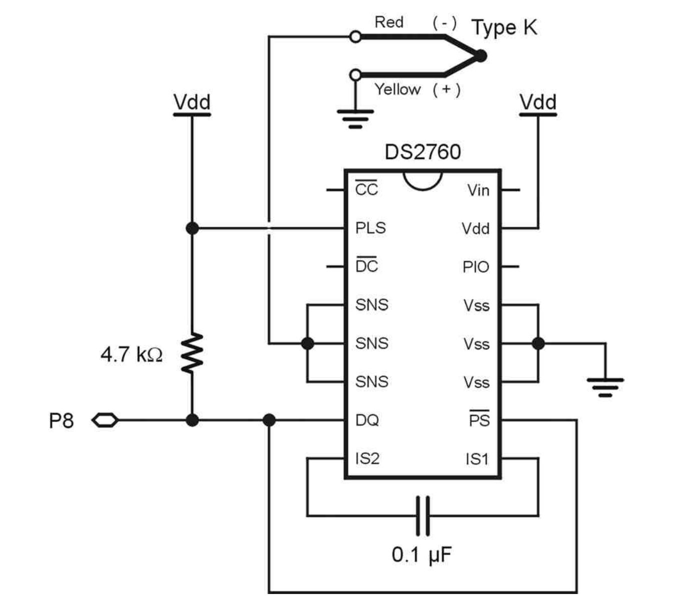


Figure 2. DS2760 thermocouple interface schematic.

(required for 1-Wire communications), we initialize the 2x8 LCD and then retrieve the serial number from the 1-Wire device connected to P8.

```
Check_Device:
  OWOUT OW, %0001, [ReadNet]
  OWIN  OW, %0010, [SPSTR 8]
  GET 0, char
  IF (char <> $30) THEN
    LCDOUT E, LcdCls,    ["NO"]
    LCDOUT E, LcdLine2, ["  DS2760"]
    STOP
  ENDIF
```

We'll send the ReadNet ($33) command to the DS2760 using **OWOUT**, specifying a front-end reset (perform the reset process before sending data). ReadNet instructs the connected 1-Wire device to transmit its eight-byte serial number.

Since we're not going to put the whole thing to use — but may want to display it later — we'll buffer it into the Scratchpad RAM using the SPSTR directive with **OWIN**. The first byte of the serial number string will be the device type; for the DS2760, this is $30. If that byte isn't $30, the program will put a message on the LCD and stop the program.

The reason we don't use **END** above — where **STOP** appears — is that **END** puts the Stamp into low-power mode. The Stamp's watchdog timer will interrupt the low-power mode every 18 milliseconds, causing the pins to "glitch" (this is a known behavior). What I saw happen in testing is that the glitch on the LCD's E pin caused the display to be blanked, obliterating the message. **STOP** halts the program without placing the Stamp in low-power mode, so the I/O pins remain in their current state without interruption.

Unless there's a problem, we shouldn't get the "NO DS2760" message and we'll move right into the main loop that measures temperature using the process described earlier. The first step is to measure the cold junction temperature. This comes from inside the DS2760.

The temperature is read from registers $18 and $19. This value is 11 bits (10 bits plus sign) and, interestingly, Bit10 (sign) is left-aligned with the MSB (Bit15) of our variable tmpCJ. Let's look at the code and then go through it.

```
Read_CJ_Temp:
  OWOUT OW, %0001, [SkipNet, $69, $18]
  OWIN  OW, %0010, [tmpCJ.BYTE1, tmpCJ.BYTE0]
  IF (tmpCJ.BIT15) THEN
    tmpCJ = 0
    error = 1
  ELSE
    tmpCJ = tmpCJ.HIGHBYTE
    error = 0
  ENDIF
  RETURN
```

To retrieve the temperature, we send the SkipNet ($CC) command (Only one device is connected, so no serial number is required.), followed by $69 (read), and then the register. Since 1-Wire devices work with bytes, our **OWIN** instruction breaks the tmpCJ variable into bytes using internal PBASIC aliases: BYTE1 (high byte) and BYTE0 (low byte).

Remember that the temperature is left-aligned within tmpCJ, so the sign is currently sitting in Bit15. If this bit is one, the temperature is negative. To keep things simple, we will disallow negative cold junction temperatures (In theory, it should be 0° C, not lower.) and set tmpCJ to zero and the error flag to one.

When the temperature is — as it will be in most cases — positive, we can convert the raw value into degrees by taking the high byte of the raw temperature. Yes, I know what you're thinking: "Huh?" Okay, here goes ... The raw value needs to be right shifted by five bits to correct the alignment.

Okay, that's easy. Then, we have to multiply by 0.125 to get whole degrees. As it turns out, 0.125 is a convenient fractional value because multiplying by 0.125 is the same as dividing by eight. And, as luck would have it, dividing by eight is the same thing as a right shift by three bits. So, in total, we have a right shift of eight bits, which means that our whole degrees result is simply the high byte of the raw temperature value.

Let me interrupt this broadcast for a minute and talk about those "convenient fractional values." While the Stamp has operators (*/ and **) that can help with fractions, there are times when we don't need to take that route. In this case, for example, we could have used the */ operator with $40 to multiply by 0.125, but it's simpler to divide by eight. Now I admit, 0.125 is a common value and easy to recognize, but what about a value like

0.0769? Here's a tip: When in doubt about a fraction that is less than one, enter it into your scientific calculator and then press the reciprocal [1/x] key. If the value is a whole number (or very very close) — cha-ching! — divide by the whole number. If that value happens to be an even power of two (2, 4, 8, 16, 32 ...), then we can use the shift operator instead of dividing, since it's faster. Okay, back to work. The next step is measuring the Seebeck voltage from the thermocouple. The process is identical to measuring temperature.

```
Read_TC_Volts:
  OWOUT OW, %0001, [SkipNet, $69, $0E]
  OWIN  OW, %0010, [tCuV.BYTE1, tCuV.BYTE0]
  signTC = tCuV.BIT15
  tCuV = tCuV >> 3
  IF signTC THEN
    tCuV = tCuV | $F000
  ENDIF
  tCuV = ABS tCuV */ 4000
  RETURN
```

The voltage is stored as a 13 bit (12 bits plus sign) value in the current registers ($0E and $0F) of the DS2760. The reason it's in the current register is that the DS2760 uses a shunt to convert a current to voltage for reading. In our application, we're using the external sense resistor version of the DS2760, which lets us measure a voltage with a resolution of 15.625 microvolts per bit. After retrieving the voltage into the variable tCuV, we save the sign by making a copy of Bit 15.

As with the temperature, the voltage is going to be left-aligned when in our word variable and the sign bit is the MSB.

After the sign is saved, we correct the bit alignment in tCuV by shifting right three bits. Now, if the sign bit is one, that means the voltage is negative and the value in tCuV is represented in two's-compliment format. Keep in mind that the shift process pads the opposite end with zeros (the high-end bits, in this case), so we need to put ones in those positions to make the two's-compliment value of tCuV correct.

This will let the **ABS** function return the right value. The final step is to multiply by 15.625 to get microvolts. As the factor is fractional and greater than one, we'll use the star-slash (*/) operator. The parameter for star-slash is calculated by multiplying 15.625 and 256.

Okay, we have the cold junction temperature and the Seebeck voltage; now, it's time to do a bit of math and determine the actual thermocouple temperature.

Turning the Tables on Tough Math

A key element of this program is the use of large tables to hold the thermocouple data. The reason we use a table is that the thermocouple output voltage versus temperature is not linear and, in fact, would require a multi-order equation to maintain accuracy. One of my favorite features of the BS2p family is the ability to use **READ** and **WRITE** across program slots. This lets us put our code in slot zero and our table(s) in slots one and higher. The **STORE** instruction is used to select a table.

To compensate for a cold junction value above 0° C, we'll determine the voltage that would be generated by that temperature for our thermocouple. This is simple; we point at our table with STORE and then calculate the address within the table by multiplying our cold temperature value by two. This is necessary, since we are using words (two bytes) to store the thermocouple output voltages.

```
  STORE PosTable
  READ (tmpCJ * 2), Word cjComp
```

Notice that we're taking advantage of a new PBASIC 2.5 feature: using the Word modifier with **READ**. The only caveat is that data must be stored in the table as low-byte, high-byte. This is not a problem for us, as we're creating the table using the Word modifier. At this point, *cjComp* holds the cold junction compensation voltage for our thermocouple. Now, it's time to combine the compensation voltage with the Seebeck voltage. After we've done that, we can do a reverse lookup in the table to determine the thermocouple temperature.

```
IF (signTC = 0) THEN
  ' TC is above cold junction
  cjComp = cjComp + tCuV
  STORE PosTable
  tblHi = 1023
  signC = 0
ELSE
  ' TC is below cold junction
  IF (tCuV <= cjComp) THEN
    cjComp = cjComp - tCuV
    STORE PosTable
    tblHi = 1023
    signC = 0
  ELSE
    cjComp = tCuV - cjComp
    STORE NegTable
    tblHi = 270
    signC = 1
  ENDIF
ENDIF
```

A bit of logic is used to do the combining for a couple of reasons. The first is that we've simplified other aspects of the code by maintaining a separate sign bit from the Seebeck voltage. The second reason is that we actually have two tables: one for positive temperatures (up to 1023° C), one for negatives (down to -270° C).

Things are easiest when the Seebeck voltage is positive. In this case, we simply add the compensation voltage to the thermocouple voltage and point to the positives table. We'll set the upper end of our table search to 1023 (this is the last Word in the table) and set the sign bit for Celsius degrees to 0, since we know it's positive.

When the Seebeck voltage sign is one (voltage is negative), this indicates that the temperature is lower than the cold junction temperature, but we don't know if it is below 0° C, so we need to apply a bit of additional logic. If the Seebeck (absolute value) voltage is less than or equal to the compensation voltage, we can subtract it from the compensation voltage and point to the positive tables, as before. When the Seebeck voltage is greater than the compensation voltage, this means that the thermocouple temperature is below 0° C. We calculate the compensated voltage by subtracting the original compensation voltage from the Seebeck value, then pointing to the negatives table.

Notice that the high end of the search for the negatives table is only 270. The reason for this, of course, is that absolute zero is -270° C. Since the temperature is negative, we will set the Celsius sign bit accordingly.

Where in the Table is My Value?

With the compensated voltage (*cjComp*) in hand, all we have to do now is find that value — or its closest match — in the table; that position will be our actual thermocouple temperature. Okay, how do we find it? One approach — the easiest — is to start at the bottom of the table and scan upward until we find a match or exceed our search value. The trouble with this method is that it can take a very long time to find a value that is in the high end of the table.

Searching large tables is nothing new and we can borrow from computer science solutions. When the table is ordered, we can use what is called a binary search. This is a divide-and-conquer approach to searching a table (or array).

To do a binary search, we'll need three pointers: the low end, high end, and midpoint of the search. We find the midpoint by adding low and high together, then dividing by two. Then, we'll check the value at the midpoint against our search value (*cjComp*). If we find a match, we jump right out of the search. If the midpoint value is not a match, we will compare it against the search value. When the search value is lower than the midpoint value, we'll reset the high end of the table search to the midpoint.

If the search value is higher than the midpoint table value, we'll reset the low end of the search to the mid-point. As you can see, we get rid of half of the available search values with every iteration of the search loop. This makes the binary search very fast and lets us find any value within 10 loop iterations.

```
TC_Lookup:
  tblLo = 0
  tempC = 22

  READ (tblHi * 2), Word testVal
  IF (cjComp > testVal) THEN
    error = 1
  ELSE
    DO
      eePntr = (tblLo + tblHi) / 2
      READ (eePntr * 2), Word testVal

      IF (cjComp = testVal) THEN
        EXIT
      ELSEIF (cjComp < testVal) THEN
        tblHi = eePntr
      ELSE
        tblLo = eePntr
      ENDIF

      IF ((tblHi - tblLo) < 2) THEN
        eePntr = tblLo
        EXIT
      ENDIF
    LOOP
    tempC = eePntr
  ENDIF
  RETURN
```

Our code is actually modified a bit from the traditional binary search. In typical applications, the search will report the position or "not found". We want the closest position if the actual value is not in the table. This

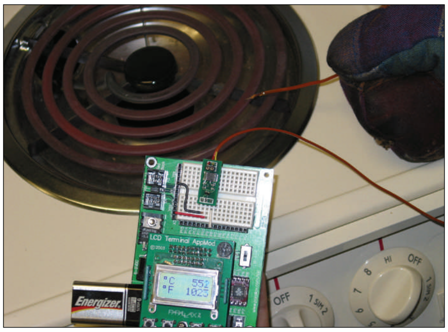


Figure 3. Don't touch ... the stove is hot!

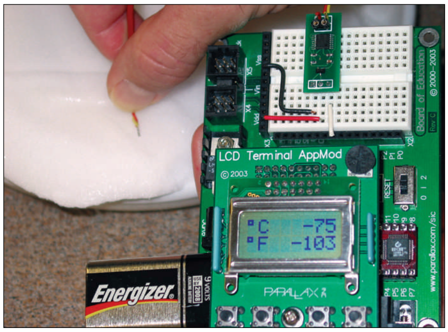


Figure 4. Dry ice is really cold!

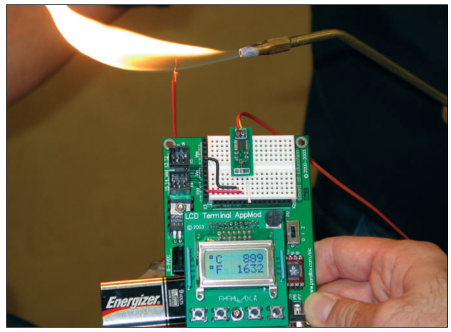


Figure 5. And torches get really hot!

is accomplished by monitoring the span between the high and low pointers. When it falls to one or zero, we've searched the whole table and we will use the low pointer as our search result.

Now that we have the correct Celsius temperature, we can convert to Fahrenheit and send the values to an LCD.

```
Display_Temps:
  IF (tempC = 0) THEN
    signC = 0
  ENDIF

  tempF = tempC * 9 / 5
  IF (signC) THEN
    tempF = 32 - tempF
  ELSE
    tempF = tempF + 32
  ENDIF
  signF = tempF.BIT15
  tempF = ABS tempF

  LOOKDOWN tempC, >= [1000, 100, 10, 0], idx
  LCDOUT E, LcdLine1, [223, "C ", REP " "\idx,
                      signC * 13 + 32, DEC tempC]

  LOOKDOWN tempF, >= [1000, 100, 10, 0], idx
  LCDOUT E, LcdLine2, [223, "F ", REP " "\idx,
                      signF * 13 + 32, DEC tempF]
```

Before we do the conversion, we'll fix the sign bit for Celsius, if required. There may be times when the temperature is just a hair below zero and the sign bit will get set. It's an easy fix.

There's no magic in converting from Celsius to Fahrenheit; we use the formula F = C x 9 / 5 + 32. As our program uses absolute values with a separate sign bit, an **IF-THEN** structure will take care of the "+ 32" part of the equation. This actually points to another reason for using absolute values: The divide operator (required in the Fahrenheit conversion) cannot be used with two's-compliment (negative) values.

To keep things on the LCD neat, I use Tracy Allen's right justification trick with REP (repeat) modifier for serial output instructions (**SEROUT**, **I2COUT**, **OWOUT**, and **LCDOUT** — even though it uses a parallel buss). A **LOOKDOWN** table is used to determine the width of our value and the width is then used to pad the display with spaces ahead of the printed value. The sign bit is used with a bit of math to print a space for positive values and a hyphen for negatives. The DEC modifier finishes the process.

Temperature Hunting

As you can see in the photos, I assembled my test unit on a standard BOE. By using a nine-volt battery, I was able to roam around and test temperatures. My first spot of interest was the hot water coming out of the tap in my hotel room; I was visiting the California office when I wrote this. How hot was it? A whopping 140° F! That's hot. However, I had access to hotter things, like that burner on the stove — over 800° F.

What about measuring cold temperatures? I picked up some dry ice at the supermarket and measured it at around minus 100° F. Wow, that is cold. *Please* ... before you go off on your own temperature hunting expeditions, be aware that you can be burned by extreme heat or extreme cold (like dry ice). I had a friend take the photos for me so that I could focus on not getting too close to the "danger zone" with my hands. Even if your thing isn't thermocouples or temperature measuring, I do hope that you found the use of tables interesting. After finishing this project, I thought of a couple other projects that could be simplified with a table; I would also get better resolution with a table than I would using integer math. You can use your favorite PC programming language to calculate values and output your table as text that can be copied into the Stamp editor. I'm currently experimenting with a very interesting multi-platform language called Python. Check it out — you might find it interesting and useful too.

Until next time, Happy Stamping. **NV**

Resources

Jon Williams
jwilliams@parallax.com
Parallax, Inc.
www.parallax.com

Tech Forum

QUESTIONS

My local middle school is using an old scoreboard system in the gym for basketball games. It worked great, but it used a mechanical timer for time outs, which would ring a bell on the console. Now, the mechanical timer no longer works and I would like to replace it with an electronic timer that can trigger a relay to activate the scoreboard buzzer. The timer will need to have two timed selections — 30 and 60 seconds — and only needs to activate the buzzer for two seconds.
#3041 **Rick**
via Internet

I need a charger circuit for a 6 V 4.5 Ah gel cell. I understand that these batteries should be charged from a constant voltage source until the battery voltage reaches 7.2 to 7.35 volts, with the current not to exceed 900 mA.
#3042 **Jay Harford**
via Internet

FM radio reception is usually poor inside office buildings, as steel in the roof and walls blocks much of the signal. Is there a way around this? Could you put an antenna outside and run a cable to another antenna inside, maybe with a broadband booster amplifier?
#3043 **Kent Durvin**
via Internet

If I isolate the two prongs of a stun gun, can I use it as a zapper to erase the "memory effect" of NiCad batteries? If not, does anyone have a schematic for a zapper that will work?
#3044 **Anonymous**
via Internet

I need a diagram to build a simple amp hour meter to drive an electromechanical counter. I have an AD645 analog to digital converter, the power supply, the counter, etc., but the circuit I put together does not work. Perhaps a fresh diagram will help me dope it out.
#3045 **Jim Buckwalter**
Visalia, CA

Does anyone have a simple circuit that uses an IR sensor to trigger a camera? I'd like to snap pictures of the nocturnal visitors in the backyard of my country home.
#3046 **Dan Gorkiewicz**
via Internet

Does anyone have a simple circuit that can be used to count the number of times a bird goes in and out of a birdhouse? I teach science to students in Michigan and I think this would help spark their interest.
#3047 **Dan Gorkiewicz**
via Internet

In the 2" x 4" framing of an outer wall of my home, I would like to install a cat door that can move up and down. I envision a motorized rack and pinion assembly. I know of a pressure sensor that would control the operating circuit, but I need some sources for electric motorized rack and pinion assemblies.
#3048 **Michael K. Lenihan**
via Internet
(Cat guillotine? — Editor Dan)

Does anyone have any suggestions as to electronic schematic development software vendors with up-to-date and extensive symbol libraries for documenting electronic projects?
#3049 **George Harayda**
via Internet

What is the best place on the web to access IC data sheets? For example, if you input 555, you get to

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This is a READER-TO-READER Column. All questions AND answers will be provided by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

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look at the pinouts of a device.

#30410 **Sassan Smarghandi**
via Internet

I have a Drake 2 A communications receiver and would like to replace the obsolete vacuum tubes (6BE6, 6BA6, etc.) with solid state devices (FETs, etc.). I would appreciate any advice or schematics that anyone can provide.

#30411 **Richard Harris**
Winamac, IN

ANSWERS

[1046 — January 2004]

I was in a shop and observed a desk clerk verify that the stone in a diamond ring was genuine. He used a probe device that became warm at the tip. It was placed against the stone in question and a red or green LED illuminated to indicate authenticity.

Electronic diamond testers work by measuring the loss of heat from a metallic probe. Diamonds are excellent conductors of heat and will draw the heat from the probe faster than simulated stones.

In recent years, moissanite — which is extremely rare in nature — has been synthesized in laboratories and its thermal conductivity approaches that of diamond, so the thermal test is not sufficient to identify a true diamond and an additional reflectivity test needs to be performed to distinguish between the two.

Diamonds have the highest thermal conductivity of any naturally occurring material. In fact, a diamond conducts heat so rapidly that it can be plunged red hot into liquid nitrogen without being harmed, whereas most non-metallic minerals would shatter (hence the popularity of diamond tipped tools). It is also exceptional in resisting electricity (think heatsink).

Depending upon the levels and nature of impurities found in diamonds, they are either extremely good electrical insulators or could have lower resistances and, in some cases, (Type IIb stones) even act as P-type semiconductors!

Diamonds are photoconductive, retaining their high resistivity only in the dark or in light with no UV content. Type IIb stones are even photoconductive to gamma rays (like a Geiger tube).

If DC voltage is applied across a Type IIb stone, at first the current will be small — perhaps a few milliamps. After a few minutes, it will rise to several amperes and the stone will become red hot and eventually vaporize if the current is not cut off. This does not seem to occur if AC is used; instead, the diamond scintillates with blue light!

Rahul Karnik
via Internet

[1043 — January 2004]

How can I burn old and

obsolete tapes and records onto CDs? I have a CD-R/W drive, but I can't figure out how to input from an outside-the-computer source.

You'll need a sound card with an external audio input jack (most cards have an "aux" jack), cables to connect to the sound card, (tape deck output, turntable/preamp output, etc.), and suitable software. The signal level output by most turntables is very low and needs to be amplified before going to the sound card, while the line-out from most tape decks can go directly to the sound card's input jack.

I personally use and recommend "Audio Cleaning Lab," by Magix. It does everything from recording with automatic track detection and placement, sound cleaning (click and hiss removal), sound enhancement (equalizer, stereo FX, etc.), to burning a CD. Visit **www.magix.com** to see everything this great program can do. Besides converting your old LPs and tapes into CDs, you can even make a little extra money providing a media conversion service to those unable to find CDs of their favorite oldies.

John McMichael
Laramie, WY

[10414 — January 2004]

I have an old TRS-80. When I loaned it out, someone overwrote the master disk. I'm looking for a replacement and will pay for a download, disk, or any fix.

The TRS-80 computer might be old, but a number of working machines are still being used on a daily basis. Stan Slater and Ron Gatlin are the publishers and editors of *Computer News 80*, which is published bi-monthly and supports the TRS-80 series of computers. They can provide disk operating systems, software and hardware, primarily for the Model III and IV.

Stan and Ron can be contacted at Computer News, PO Box 50127, Casper, WY 82605-0127 or **compnew@trib.com**

John Hemminger
Brookfield, MO

[1049 — January 2004]

I salvaged some lithium-ion rechargeable batteries and need to build a charger for them. They are 3.6 V, 1200 mAh in size. Can I use my NiMH battery charger?

Lithium-ion batteries need a special charger to recharge them. Trying to use a NiCD or NiMH charger will either ruin the battery, cause a fire, or do nothing (if the protective circuitry works).

Go to Maxim's website **(www.maxim-ic.com)** to learn more about Li-ion battery charge circuitry. Search on their website for "battery management," there is a lot of information about the chips they make for battery charging.

Robert Zusman
Scottsdale, AZ

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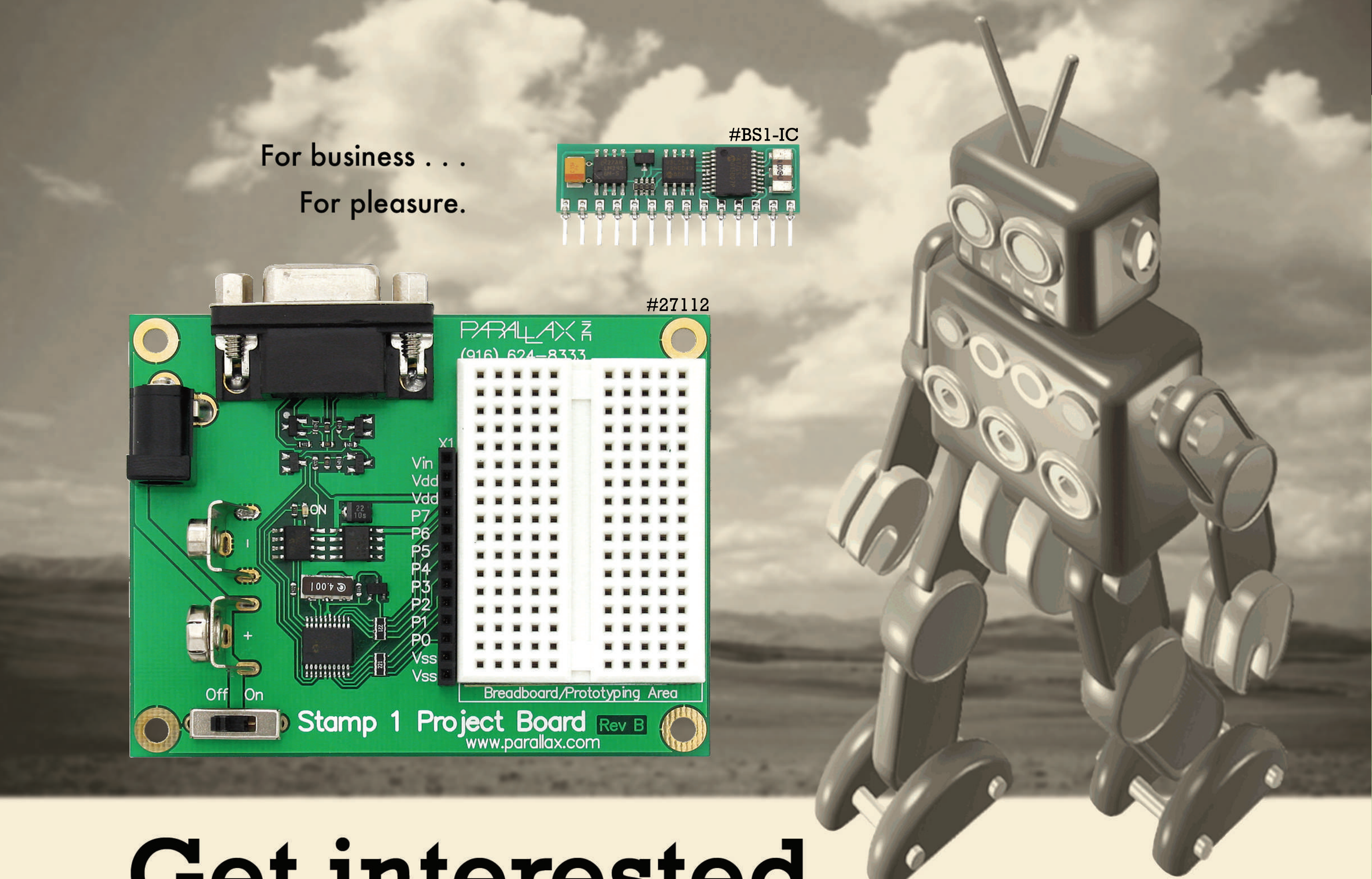

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